THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Basic Refractories: Properties and Uses

J. R. RAIT: 'Basic Refractories; Their Chemistry and Their Performance.' *Published by Iliffe and Sons, Ltd.*, London, 1950. 408 pp. Price £3 0s. 0d.

The scattered knowledge of the subject has been usefully correlated in this volume, which covers both the theoretical and the practical aspects. The author, who has been associated with much of the recent work in this field, has combined his own experience with much information from published and unpublished sources, making the resultant survey the most comprehensive one which has yet appeared.

The main chapters cover, respectively, the processing of basic refractories; their components (phase relations of CaO, MgO, SiO_2, Al_2O_3 and Fe_2O_3); available phase-equilibrium data; experimental investigation by the author and other investigators; the constitution of dolomite, magnesite and forsterite refractories; the constitution of chrome-magnesite refractories; formation of liquid in basic refractories; performance characteristics and the factors affecting them.

A *bibliography* of 219 references is appended.

Cold Working of Non-Ferrous Alloys: Institute of Metals Symposium

See abstract on p. 77.

Cleaning of Metals Prior to Electroplating: Literature Review

See abstract on p. 69.

NICKEL

Influence of Basis-Metal Composition in Oxide-Coated Nickel Cathodes

R. FORMAN and G. F. ROUSE: 'Oxide Cathode Base Metal Studies.' *Jnl. Research, Nat. Bur. Standards*, 1951, vol. 46, Jan., pp. 30-7; R.P. 2171.

The composition of the metal serving as a base for the oxide coating of cathodes in thermionic valves is widely recognized as a source of uncertainty in cathode behaviour, and in this connexion some study has already been made of the influence of small amounts of other metals which may be present in the nickel used. These investigations have not, however, indicated conclusively the rôle of composition, and tube manufacturers still generally consider it unwise to accept or reject a new melt of cathode nickel solely on the basis of composition.

The work reported in this paper is part of an investigation undertaken to obtain additional information on the behaviour of the nickel-base material as a function of composition, particular attention being centred on the influence of magnesium content as affecting thermionic performance. The choice of magnesium for study was dictated by its relatively high reducing action on an oxide coating.

In the first section of the paper a description is given of a double-diode test set-up devised to compare cathodes of high-purity and of magnesium-containing nickel; the second contains results of comparative tests, made with this device, on cathodes of (1) nickel containing magnesium 0·18, carbon 0·01, sulphur 0·01, per cent., and (2) high-purity electrolytic nickel, containing about 0·01 per cent. each of copper and lead, with only traces (less than 0·01 per cent. each) of magnesium, manganese and silicon. Data on the influence of magnesium on the rate of electrolytic activation and on the life of an oxide cathode are shown in a series of curves, and the influence of the cathode and anode on pulsed-current decay at high current densities is also discussed.

Nickel Plating as Protection against Solder Attack

See abstract on p. 90.

Factors Affecting Activity of Raney Nickel Catalysts

J. N. PATTISON and E. F. DEGERING: 'Some Factors Influencing the Activity of Raney Nickel Catalyst. II. The Rôle of Oxygen in the Ageing of Raney Nickel Catalyst.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Jan., pp. 486-7.

Observations previously reported are somewhat contradictory with regard to the keeping properties of Raney nickel; statements in the literature are briefly summarized. The present authors record results indicating that oxygen is responsible for a large proportion of the ageing which they found to occur in catalyst of the W-4 type. The data from which such conclusion is drawn are reported in the note.

Ferromagnetic-Resonance Measurements on Nickel Films

J. R. MACDONALD: 'Ferromagnetic Resonance Measurements on Stressed Nickel Films.' *Physical Rev.*, 1951, vol. 81, Jan. 15, p. 312 (Abs. only).

Previous measurements, by Griffiths and Standley (1948), on thin annealed nickel films, at wave lengths of 1·23 and 3·04 cm., showed the possibility of considerable dependence of the Landé *g*-factor upon film thickness. Measurements made by the present authors indicate that these results were largely caused by thickness-dependent isotropic plane tension. The measurements on which this conclusion is based were carried out at a wave length of 1·25 cm., on nickel films from 0·05 to 3 microns thick, evaporated on mica. The results are briefly summarized in this abstract of a paper read before the American Physical Society, Nov., 1950.

Measurement of Stress in Nickel Films

J. R. MACDONALD: 'Measurements of the Stress in Nickel Films with New Oscillation Magnetometer.' *Physical Rev.*, 1951, vol. 81, Jan. 15, p. 328 (Abs. only).

Using a new oscillation magnetometer, a description of which is to be published in the *Journal of Scientific Instruments*, isotropic planar stress was measured in thin nickel films evaporated on mica, and still attached to the base. The measurements were made on films in which ferromagnetic-resonance measurements (see preceding abstract) had indicated that there was virtually no cross-sectional stress dependence.

The results demonstrate that the *g*-value of nickel films is independent of film thickness and stress, and is of the same order as that found for bulk nickel.

Production and Properties of Nickel-Oxide Films containing Lithium

M. C. JAMISON and T. R. KOHLER: 'The Preparation of Thin Films of NiO with Lithium Impurity.' *Physical Rev.*, 1951, vol. 81, Jan. 15, p. 322 (Abs. only).

Verwey and co-workers have shown that by substituting lithium for nickel in the NiO lattice the conductivity of the oxide may be varied through a wide range. The present authors prepared mixtures of nickel and lithium on polished fused quartz discs, by simultaneous vacuum deposition of the two metals. The metallic films were converted to oxides by heating to 500°C. in a stream of nitrogen containing a small amount of oxygen. Satisfactory semi-conducting films were obtained in the thickness range from a few hundred A to 3000 A. The lithium content was varied from 2 to 48 at. per cent.

T. R. KOHLER and N. C. JAMISON: 'The Electrical Properties of Thin Films of NiO with Lithium Impurity.' *ibid.*, p. 322 (Abs. only).

Report of measurements to establish the relationship between resistivity and lithium content over the range 2-48 per cent. lithium. The curve shows a broad minimum in the region of 30 at. per cent. lithium. Temperature coefficient of resistance was measured for the interval 30° to 60°C.

(Both papers were presented to the American Physical Society, Nov., 1950.)

ELECTRODEPOSITION AND OTHER COATING METHODS

Cleaning of Metals Prior to Electroplating: Literature Review

H. B. LINFORD: 'Cleaning and Preparation of Metals for Electroplating; 1, Critical Review of the Literature.' *Plating*, 1950, vol. 37, Dec., pp. 1265-9; 1951, vol. 38, Jan., pp. 60-5; Feb., pp. 158-66.

Report issued under the aegis of A.E.S. Research Project 12, which has for its initial purpose the establishment of standards of cleanliness for metallic surfaces being prepared for electroplating, and the development of tests which may be used to ensure compliance with such standards.

The literature review prepared as the initial stage in the work envisaged is presented in the following classification, and is supported by a *bibliography* of 192 references:—

(1) Introduction, discussing the need for metal cleaning.
(2) Types of soil, organic and inorganic.
(3) Methods of metal cleaning (by means of alkaline, solvent, solvent-emulsion, and alkaline copper-cyanide cleaners, and by descaling media).
(4) Standards of cleanliness (nature of adhesion, origin and effect of films, effect of surface condition of the metal on degreasing).
(5) Methods of evaluating cleanliness (indirect and direct).

Surface Smoothness: Levelling in Electrodeposited Metals

At the 1950 Annual Convention of the American Electroplaters' Society several papers were presented relating to the nature of surface smoothness, methods of measurement of surface finish, and the levelling effects obtainable by electrodeposition and other methods. Brief notes on the individual contributions to these discussions are given below:—

H. L. KELLNER: 'Measurement of Surface Smoothness.' *Proc. 37th Ann. Convention, Amer. Electroplaters' Soc.*, 1950, pp. 105-22; disc., pp. 122-4.

A review is made of methods which have been proposed for measurement of surface smoothness. The discussion is classified under the headings of microscopic methods; the micro interferometer; electromechanical instruments (Profilometer, Brush Surface Analyzer); acoustical methods; replica techniques; the electron microscope; methods involving reflectance measurement.

A. G. STRANG and F. OGBURN: 'Measurement of Surface Brightness of Electrodeposited and Electropolished Surfaces by Means of the Microinterferometer.' *ibid.*, pp. 125-36.

This instrument, developed and built during the war period at the Carl Zeiss Works at Jena, has not yet become commercially available, but in view of its potential value as a means of studying the surfaces of electrodeposits, a description of it was included in the symposium. It is stated to be capable of giving absolute measurements of surface irregularities ranging from 2 to 80μ in. (0·05-2μ) on highly reflective samples, and from 2 to 10μ in. (0·05 to 0·25μ) on the more reflective of matte surfaces. Design, operation and interpretation of interference micrographs are discussed. Typical examples of such micrographs given in the paper include examples of bright-nickel deposits made on stainless-steel surfaces of various types; matte deposits of nickel from an all-chloride bath; dull and bright nickel deposits made on steel surfaces which had received various polishing treatments; and nickel-chromium finish on a bumper bar, showing a small nodule.

C. L. FAUST: 'Smoothing by Electropolishing and Chemical Polishing.' *ibid.*, pp. 137-50; disc., p. 150.

The smoothing or levelling producible by (1) electropolishing, and (2) chemical polishing was compared with that resulting from mechanical polishing, using, as criteria, surface roughness-gauge data, reflectivity measurements and the appearance of photomicrographic reproductions of the surface. In most of the examples given, stainless steel was the material used.

The results show that electropolished surfaces are superior to mechanically buffed surfaces, or high mill finishes, in that they give less diffuse reflection of incident light, and, therefore, a richer and clearer colour. Effects obtainable by a combination of mechanical polishing, electropolishing, and bright-nickel plating are illustrated, in comparison with surfaces plated without electropolishing. The extent to which different degrees of electropolishing can produce levelling is also illustrated.

With regard to chemical polishing, it is pointed out that such treatment produces a good degree of lustre on many non-ferrous metals and alloys, and that it approaches electropolishing in its levelling action, with the added advantage that the bath does not cause etching, a feature differentiating it from the usual bright-dipping process, in which time of immersion is critical if etching is to be avoided.

Another aspect of levelling discussed by the author is the value of electropolishing as a method for preparation of surfaces to be used under conditions in which avoidance of friction is important. Seizure-test results on steel shafts working against (1) mechanically polished, and (2) electropolished, silver bearings exemplify the improvement obtainable by the higher surface finish produced by electropolishing of the steel surfaces.

The final section of the paper contains data demonstrating the value of electropolishing in the preparation of materials for electroplating. Structure and adhesion of nickel deposits made on mechanically and on electropolished steel illustrate the differences in the orientation of the nickel deposits, and the superior degree of adhesion resulting from deposition on a metal from which the worked surface has been removed. Clarification of terminology on adhesion, bond-strength and kindred terms is considered highly desirable as a contribution towards improving the quality of electrodeposits.

G. W. JERNSTEDT: 'Levelling with P.R. Current Plating.' *ibid.*, pp. 151-67; disc., pp. 167-70.

Brief notes on the three methods generally used for obtaining levelling (mechanical, chemical, and electrochemical) are followed by a report of study of the influence of the variables affecting the degree of levelling obtainable with the P.R. plating process, which, although developed primarily for use with cyanide-copper electrodeposition, is not limited to this application. A brief outline of the essential features of the P.R. plating method is given, and a review is made of conclusions which have been drawn from a study of the influence, on the levelling obtainable by it, of current density, thickness of deposit, agitation, composition of solution, the use of a proprietary addition agent (WES-X), and contamination of the solution.

Typical structures obtainable by the P.R. plating process are illustrated, and its practical application in commercial electrodeposition is discussed.

C. E. REINHARD: 'Some Observations of the Microthrowing Power of Plating Solutions.' *ibid.*, pp. 171-83; disc., p. 183.

During earlier investigation of the plating of metal-powder parts it was observed in microsections that the deposits extended into surface and sub-surface voids, some of which were several thousandths of an inch below the surface. Although frequently the surface pores were completely filled, and the deposit had levelled the surface, the degree of fill varied considerably with the different types of coating.

The ability of a plating bath to deposit metal in pores is defined as its microthrowing power, and it is recorded that, contrary to experience in relation to ordinary throwing power, in the plating of irregularly-shaped objects, nickel and acid-copper solutions have better microthrowing power than cyanide-copper baths. Even chromium can be deposited in minute crevices of considerable depth.

Following tests in which it had been confirmed that the phenomenon observed in brass-powder parts was reproduced in micro-grooved brass parts, a study was made of pore-filling capacity (micro-throwing power), using, as basis material, specimens having grooves approximately 0·0012 in. (30 μ) in width and 0·0035 in. (90 μ) deep. The study covered effects of pH, temperature, current density, metal content of the plating solution, type of basis metal (copper, silver, steel), thickness of deposit, cathode motion, position and size of groove, and anode-cathode spacing.

The nickel-plating solutions used in the main investigations were of three types: (1) dull, (2) dull ammonium-free, and (3) bright. A few deposits were also made from chromium, cyanide-zinc, sulphate-zinc, chloride-zinc, cyanide-copper, acid-copper, and high-sodium-sulphate nickel solutions.

The results are recorded in considerable detail, in a series of curves and photomicrographs illustrating the degree of filling and levelling obtained under the various conditions used.

It is noted with regard to the nickel-plating experiments, which formed the major part of the investigation, that the greatest effects on microthrowing power were produced by variation in the metal content of the solution and the current density. High metal contents yielded a high thickness ratio; low metal contents, a low one. There appeared, however, to be a limiting metal concentration beyond which no further improvement was observed. Increase in current density at any given metal content level decreased the thickness ratio; the effect was most clearly marked in solutions of low metal content. Raising the temperature of operation increased microthrowing power, offsetting, to some extent, the current-density effect. Differences in the microthrowing-power characteristics of the different nickel solutions appeared to be associated mainly with their relative metal contents:

the addition agent in the bright-nickel bath had comparatively little effect. Groove position, thickness of coating, and agitation caused only minor variations in microthrowing effect, and anode-cathode spacing, pH, solution-resistivity, and the nature of the basis metal had no influence on the results. It is concluded that metal-ion availability at the cathode is the major controlling factor, and it is believed that the influence of all the other factors studied is probably only a measure of the extent to which they affect the metal-ion concentration.

The results of the experiments did not lead to an understanding of the mechanism by which microthrowing power functions, and the author considers that any adequate explanation of the phenomenon is unlikely until the reactions taking place in a cathode film, and the electrical characteristics of a porous cathode surface, are more clearly understood.

L. WEISBERG: 'Levelling in Cobalt-Nickel Plating Solutions.' *ibid.*, pp. 185-91; disc., p. 191.

As a criterion, deposits from a Watts-type nickel-plating solution provide a reference point for evaluating levelling action, since such a solution, if well purified and correctly operated, produces substantially no gain or loss in surface roughness. Impurities cause roughening, to an extent making it possible to apply increase in roughness as a gauge of purity of bath. Another nickel solution which has been found to have no levelling action is the original cobalt-nickel bath operated in accordance with the Weisberg and Stoddard patent. (*U.S. Pat.* 2,026,718; 1936).

Ability to produce levelling and brightness are separate attributes; a solution may produce the one effect without the other, but certain solutions achieve both effects simultaneously.

Addition of cobalt to a Watts-type nickel solution does not of itself result in levelling action, but the presence of formic acid produces a levelling effect, and in this case a cobalt-nickel solution gives better levelling than a plain nickel solution containing an equal amount of formic acid. The preferred amount of cobalt is of the order of 1 per cent.; higher percentages do not give sufficient improvement to justify the additional cost involved. A solution which has proved to give good levelling action is of the following composition.

	oz./gal.	g./L.
Nickel sulphate (single salts)	48	360
Nickel chloride	4	30
Formic acid	2	15
Boric acid	5·5	40
Cobalt sulphate	0·4	3
Formaldehyde solution (40%)	up to 0·35	up to 2·6

The amount of formaldehyde used and the operating conditions chosen depend on whether the solution is to be operated in the semi-bright or in the bright range.

Initial purification of the solution is done in the same manner as for bright-nickel baths and the conditions of electrolysis are substantially similar. The author has found it advantageous to replace part of the nickel anodes in the auxiliary tank by graphite anodes, which assist by destroying oxidizable organic matter. It is also noted that the amount of activated carbon and clay required for good levelling effect is somewhat larger than that necessary in bright-nickel plating. Recommended maximum permissible limits recommended for common metallic impurities are given as under:—

	oz./gal.	g./L.
Aluminium	0·001	0·008
Cadmium	0·001	0·008
Chromium (trivalent) ..	0·0001	0·0008
Chromium (hexavalent) ..	0·0001	0·0008
Copper	0·001	0·008
Iron (ferrous)	0·0001	0·0008
Iron (ferric)	0·01	0·08
Lead	0·001	0·008
Zinc	0·001	0·008

It is noted that chromium and ferrous iron are the most dangerous of these impurities.

With regard to organic impurities it is noted that traces of oil can cause complete loss of levelling: treatment with activated carbon fully restores the action. Information already generally available with regard to the influence of organic impurities in bright nickel-plating solutions is valid, in broad outline, for baths of the type under consideration. Some wetting agents have been found to be detrimental to levelling, but it is not yet known whether the effect is due to the agent itself or to some accompanying impurity. No wetting agent yet investigated has been found to have any beneficial influence on levelling. Ammonia and ammonium salts should be excluded.

Agitation of the solution is preferably obtained by means of oil-free air; permissible current densities go up rapidly if sufficient agitation is provided.

The paper includes some data on the degree of levelling (as gauged by a Brush Surface Analyzer) under given conditions, and it is noted that, on the basis of the known properties of the deposits, it would be anticipated that their tensile strength, elongation, stress and hardness characteristics would be closely comparable with those of deposits made from Watts nickel solutions. Corrosion-resistance of the deposits is, so far as the author is aware, of the same order as that of other cobalt-nickel deposits. If the theory that plating on a rough surface lowers corrosion resistance be valid, a solution which would cause levelling action might be expected to produce deposits of improved corrosion-resistance.

A. H. DUROSE, W. P. KARASH and K. S. WILSON: 'Surface Contour and Levelling.' *ibid.*, pp. 193-212; disc., pp. 212-13.

This paper is a discussion of available data on (1) levelling by electrodeposition from a solution which will give a deposit having a smoother surface than the basis material, and (2) levelling by polishing and buffing. Discussion of observations made with regard to deposit distribution (of nickel) in and adjacent

to small scratches indicates the need for further research. Proposals are made for methods of studying the problems presented, with emphasis on the need for a more fundamental understanding of the processes occurring at the cathode under various conditions.

'General Discussion of Levelling.' *ibid.*, pp. 215-22.

Contributions to the discussion were made by:—

J. J. DALE, who presented (1) illustrations exemplifying microthrow in a Watts-type nickel-plating solution, and (2) measurements of viscosity, resistivity and metal content of anode-film material obtained by scraping stainless-steel test pieces which had been electropolished in phosphoric-sulphuric acid bath, withdrawn, and allowed to drain. Values are shown in comparison with similar data on samples of electrolyte from the body of the solution.

R. F. LEDFORD, who reported levelling experiments in barrel plating with zinc.

M. B. DIGGIN, who presented tabular data showing observations of (1) effect of anodic pickling on smoothness of S.A.E. 1020 steel; (2) effect of electropolishing the same steel in aqueous sulphuric acid-orthophosphoric acid solutions; (3) effect of electropolishing Watts- and cobalt-containing nickel deposits (instead of the basis metal); and (4) the levelling action produced by various types of nickel, copper and cadmium bath. The data so tabulated are the result of observations made over a two-year period by the Hanson-Van Winkle-Munning Company.

The nickel-plating baths for which data are shown were of the following types: cold; Watts purified; bright, organic; semi-bright, organic; chloride-acetate; all-chloride; fluoborate; cobalt-nickel. On the results the following comments are made:—

'There was no appreciable roughness reduction in the cold nickel solution. The same is true in the purified Watts bath; in fact roughness increases with heavier deposits.

'The four organic-brightener nickel solutions all show some levelling, with the semi-bright-nickel solution exhibiting a high degree of levelling. In the chloride-acetate solution used for plating on stereotypes, which was described by Peters (see abstract on this page) the roughness remains practically unchanged, which is an important feature when applying nickel to stereotypes, because a faithful reproduction of the surface is required for printing.

'The fluoborate nickel solution without any addition agent, as originally prepared, produced an appreciable levelling, but when the solution was purified by electrolysis and carbon treatment, it did not show any levelling ability. Upon the addition of copper as an impurity, the levelling action was restored.

'Cobalt-nickel solutions modified to give levelling characteristics produced deposits much smoother than the base upon which they were applied. The data given in the table show that deposits become smoother as thickness is increased.'

Nickel Plating as Protection against Solder Attack

See abstract on p. 90.

Carbon-containing Nickel Anodes

HENRY WIGGIN AND CO., LTD.: 'Rolled Carbon-bearing Nickel Anodes.' *Publn.* 478*, 1951; 2 pp.

This small pamphlet briefly calls attention to the advantages of carbon-containing anodes for use in bright-nickel-plating solutions operating at a pH below 4·5. Recommendations are made for operation with these anodes, including particulars of required current density, nature of bath for which they are best suited, length of anode relative to the cathode frame, and bagging.

Electrodeposition in the Printing Industry: Historical Review

E. I. PETERS: 'Advances in Electrodeposition in the Graphic Arts.' *Proc. 37th Ann. Convention, Amer. Electroplaters' Soc.*, 1950, pp. 69-84.

The paper deals primarily with recent advances in the graphic-arts industry, but includes also a review of all printing processes which use electrochemistry in the production of printing plates. This includes the three major printing procedures; letterpress, offset lithography, and intaglio or gravure. Methods used in each of these processes are described, with diagrams and tables illustrating the stages at which electrodeposition is employed. Individual sections of the review contain flow sheets, and much useful information, on rotogravure plate making, bimetallic lithographic plates, stereotyping, and electrotyping.

The past few years have seen gradual but definite technological advance in the printing industry. Bimetallic lithography is mentioned as a definite innovation, the potential usefulness of which is not yet fully realized, and another recent development is the use of magnesium plates, in place of copper or zinc, in the photo-engraving field. This latter change has been made possible only by the use of electrodeposited coatings of copper and chromium, which have the further advantage of providing printing surfaces which are capable of withstanding a large number of impressions. It is, however, in connexion with process improvements that most of the electrochemical advances in this field have to be recorded. Major developments are concisely described by the author, under the following headings:—

(1) *Chloride-Acetate Bath for Nickel-Plating of Stereotypes.* Details are given of the rapid nickel-plating process introduced in 1947 by Lalonde, which is now regarded as well-established industrial process. For details see *Nickel Bulletin*, 1949, vol. 22, No. 12, p. 193.

(2) *Tin-Plating of Electrotype Shells*, using a tin-fluoborate solution, details of which are given.

(3) *Cobalt-Nickel Solutions for Electrotyping.* This development was described in *Plating*, 1949, vol. 36, pp. 560-5; *Nickel Bulletin*, 1949, vol. 22, Nos. 8-9, p. 137.

The present author, who is associated with Pontiac Engraving and Electrotype Company, reports that in

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his plating shops some changes have been made from the original cobalt-nickel solution. Composition and operating conditions now used are as given below:—

	oz./gal.	g./L
$NiSO_4.7H_2O$	32	240
$NiCl_2.6H_2O$	4	30
H_3BO_3	1·5-2·5	11-19
$Ni(COOH)_2$	0·5-1·5	3·8-11
$CoSO_4.7H_2O$	0·35	2·6
Temperature	120°F. (50°C.)	
pH (electrometric)	5·1-5·4	
Current density	25 amp./sq. ft. (2·7 amp./sq. dm)	
Voltage	6-volt	
Agitation	Air	
Anode-cathode spacing ..	4½ in. (11 cm.)	
Anodes	1% Co, 98+% Ni	

Notes are added on the considerations which have dictated some of the modifications made.

The advantages of the cobalt-nickel deposits are two-fold: faster deposition, and longer press life. In the latter connexion, simulated-service tests have indicated that the life of cobalt-nickel deposits should be 57 per cent. longer than that of nickel deposits. Service records are quoted, showing that whereas one million impressions have been regarded as a good run for a curved nickel type from a type form, curved cobalt-nickel electrotypes from type forms have run as many as 2,900,000 impressions before appearance of the first signs of copper.

(4) *Copper-Fluoborate Electrotyping Solution.* This solution, introduced by STRUYK in 1949, has, to date, been used, so far as the writer is aware, only in the plating shops in which it was developed. Its potential value would, however, indicate that it may be more generally adopted in the future.

(5) *Copper-Fluoborate Rotogravure Plating Solution.* A solution of the same composition as that employed in electrotyping is now being used for plating of rotogravure cylinders. It permits use of higher current densities, and hence shorter plating times, and it is also claimed that less grinding is required to remove roughness caused by anode sludge, and that the deposits have a finer grain, resulting in increased printing life.

(6) *Iron Plating of Electrotypes.* This development is of academic, rather than commercial, interest. Iron plating received some degree of attention during the war period, but has been abandoned since then. The latest work is that of SCHAFFERT and GONSER (*Electrotypers' and Stereotypers' Bull.*, 1943, vol. 29, pp. 23-32) relating to a sulphate-chloride bath.

(7) *Nickel Fluoborate for Stereotypes.* The use of nickel-fluoborate baths for plating of stereotypes was described by KOESSLER and SLOAN (*Electrotypers' and Stereotypers' Bull.*, 1950, vol. 36, Mar., pp. 33-7).

See also following abstract.

The review is supported by a useful *bibliography* (33 items) giving reference to original papers describing the respective developments discussed.

Nickel Plating of Stereotypes

K. L. KOESSLER and R. R. SLOAN: 'High-Speed Nickel Plating of Curved Stereotypes.' *Proc. 37th Ann. Convention, Amer. Electroplaters' Soc.*, 1950, pp. 85-9; disc. pp. 89-90.

The paper describes a new plating solution recently made available by General Chemical Division, Allied Chemical and Dye Corporation, Buffalo. It is claimed to produce the desired structure of the deposit, and to be characterized by ease of control, very high rate of deposition, stability with regard to change of pH, and economy in operation.

The following details are given of procedure which has been found satisfactory:—

(1) Cleaning of Stereotypes

Alkaline cleaning: 8-12 oz./gal. (60-90 g./L) of trisodium phosphate; 190°F. (88°C.); voltage, 6; direct current 3-4 min., reverse current 5-10 sec.; c.d. 30 amp./sq. ft. (3·2 amp./sq. dm.)

Cold Water Rinse and Spray

Acid Dip: 10 per cent. fluoboric acid; room temperature; 10-15 sec.

Cold-Water Rinse and Spray

(2) Composition of Plating Bath

	g./L	oz./gal.
Nickel fluoborate, $Ni(BF_4)_2$	220	29·3
Nickel, Ni	55	7·37

(3) Operating Conditions

Baume at 80°F. (27°C.), 19-21; pH (colorimetric) 3·0-4·5; temperature 90°-110°F. (32°-43°C.); tank voltage, 6·6; average cathode current density (no agitation) 75 amp./sq. ft. (8·1 amp./sq. dm.); anodes, rolled, depolarized nickel.

It is noted that the bath is extremely stable, with a minimum of sludging, shown by the long periods intervening before cleaning and re-charging of the filters is required. Pitting is easily controlled by small additions of hydrogen peroxide, preferably added near the discharge from the filter, to ensure intimate mixing with the solution being treated. The nickel-fluoborate bath, operated under the conditions described, gave a cathode efficiency of 95-97, and an anode efficiency of 99-100, per cent. Rates of deposition obtained at various current densities are tabulated, showing the high production speeds obtainable.

Results obtained in a 60-day test period have led to complete changeover, in the works of Allied Chemical and Dye Corporation, to the new type of bath.

Electroplating in Germany, 1940-1950

R. SPRINGER: 'Electroplating and Metal Finishing Developments in Germany, 1940-1950.' *Proc. 37th Annual Convention, Amer. Electroplaters' Soc.*, 1950, pp. 99-102; disc., p. 103.

Review, supported by *bibliography* of 100 items. Sections on German developments in cleaning; deposition of nickel, chromium, zinc, silver and gold, iron; oxidation and surface treatment of aluminium- and magnesium-base materials; oxidation of iron and steel; phosphatizing; miscellaneous developments in coating; methods of testing. The only paper to which attention is directed in the nickel section is that by RAUB and WITTUM, in *Zeitschrift für Elektrochemie*, 1940, vol. 46, pp. 71-82; *Nickel Bulletin*, 1940, vol. 13, Nos. 7 and 12, pp. 138 and 217.

Nodule Method for Measuring Adhesion of Electrodeposited Coatings

A. BRENNER and V. D. MORGAN: 'The Nodule Method of Measuring the Adhesion of Electrodeposited Coatings.' *Proc. 37th Ann. Convention, Amer. Electroplaters' Soc.*, 1950, pp. 51-65; disc., pp. 66-7.

Following a condensed critical review of methods which have been previously proposed for measuring adhesion of electrodeposited coatings, a detailed description is given of a new procedure developed at the National Bureau of Standards.

Previous experience has indicated that the major problem in developing a satisfactory adhesion test for coatings is the provision of a grip sufficiently strong to make possible detachment of the electrodeposited layer from the basis material. In the new method this is overcome by electroforming an adherent, mushroom-shaped projection on the surface of the coating, to act as the grip.

A full and well-illustrated account is given of the four steps involved in the test: (1) definition, by means of a hole in a plastic disc or washer, of the area on which the grip nodule is to be deposited, and masking of the remainder of the surface; (2) preparation of the unmasked surface areas by cleaning, electrolytic etching, and striking in a dilute cobalt-chloride solution; (3) electroplating the prepared surface from a hot cobalt-chloride solution until a nodule has been built up; (4) removal of the plastic washer and stop-off, and measurement, with a spring balance, of the force required to detach the coating.

Determinations of the influence of thickness of coating, on force required for detachment of the nodule, indicate that, except on very soft basis metals, e.g., lead, this effect is negligible.

It is pointed out that the degree of adhesion which can be measured by this method is limited by the strength of the nodule used as grip, but that as electrodeposited cobalt has a tensile strength of about 75,000 p.s.i. (33·5 tons per sq. in.) the test should prove satisfactory for measuring the adhesion of most commercially plated objects. It is conceded that the method has the drawback that it must be performed in a laboratory, by a skilled technician, and that it is time-consuming, but, conversely, it has the following major advantages: (1) it does not require the use of specially shaped test pieces; (2) no machining operations or expensive physical-testing apparatus is necessary; (3) the results are expressible in terms of ordinary mechanical units.

A problem still requiring solution is that cobalt nodules will not adhere with sufficient tenacity to enable tests to be made on bright-nickel-plated surfaces. The matter is being further investigated, with a view to extending the general applicability of the test. The method has not yet been applied to adhesion testing of chromium coatings.

Properties and Applications of Electroformed Nickel

'Electroforming: A Mass-Production Tool.' *Steel*, 1951, vol. 128, Feb. 12, pp. 77-80.

Parts made by electroforming ('cold casting') are now being used on a large scale in the automobile, aircraft, radio, radar, glass, printing, rubber-tyre, steel, and other industries. This article summarizes the advantages of the process and the properties of some electroformed metals in regular use. The process is particularly useful for forming tube- and cup-like shapes, since it is thus possible to avoid repeated drawing and annealing operations.

Table I shows solutions used for electroforming of nickel, copper and iron (the metals most generally

Table I
Plating Solutions for Electroforming

	Soft	Medium	Hard
Nickel			
Nickel sulphate	44 oz./gal.	—	24 oz./gal.
Nickel chloride	6 oz./gal.	40 oz./gal.	—
Ammonium chloride	—	—	3·3 oz./gal.
Boric acid	5 oz./gal.	4 oz./gal.	4·0 oz./gal.
Temperature	115°-140°F. (46°-60°C.)	140°F. (60°C.)	110°-140°F. (43°-60°C.)
Current density	25-100 amp./sq. ft.	25-100 amp./sq. ft.	25-50 amp./sq. ft.
Copper			
Copper sulphate (crystals)	27 oz./gal.		
Sulphuric acid	65 oz./gal.		
Temperature	75°-120°F. (24°-50°C.)		
Current density (average)	15-40 amp./sq. ft.		
Iron			
Ferric chloride	50 oz./gal.		
Calcium chloride	25 oz./gal.		
pH	6 to 10		
Temperature	185°-195°F. (85°-90°C.)		
Current density (average)	50-100 amp./sq. ft.		

Table IIa
Physical Properties of Electrodeposits

	Hardness (Vickers)	Ductility (% elongation in 2 in.)	Ultimate Tensile Strength	
			p.s.i.	t.s.i.
Copper	80	22	36,000	16·1
Iron	240	15	50,000	22·3
Soft nickel	140-160	30	51,000	22·8
Medium nickel	230-260	21	98,000	43·75
Hard nickel	350-475	6	150,000	66·95

Table IIb
Properties of Various Electroformed Metals

Metal	Hardness, Brinell or Vickers	Tensile Strength	Elongation* %
Nickel			
Hard, stress-free, as-formed	130-500	Up to 132,000 p.s.i. (59·0 t.s.i.)	Up to 20
Very hard, as-formed	400-575	Up to 160,000 p.s.i. (71·45 t.s.i.)	Up to 9
Very hard, stress-annealed	300-400	Up to 90,000 p.s.i. (40·20 t.s.i.)	Up to 30
Fully annealed, recrystallized	No data	45,000-55,000 p.s.i. (20·10-24·5 t.s.i.)	Up to 50
Copper			
Stress-free, as formed	30-120	30,000-68,000 p.s.i. (13·4-30·40 t.s.i.)	5 to 20
Cold-worked, ductile	65	Up to 102,300 p.s.i. (45·65 t.s.i.)	40
Iron			
Stressed, as-formed	225-350	50,000-110,000 p.s.i. (22·3-49·1 t.s.i.)	5 to 20
Annealed	140-165	40,000-55,000 p.s.i. (17·85-24·55 t.s.i.)	27 to 40
Cobalt			
As-formed	150-375	No data	No data
Silver			
As-formed	50-300	No data	No data

* Reported in most cases as elongation in two inches. Based on data reported by Battelle Memorial Institute.

used) and Tables IIA and IIB give properties typical of the electroformed metals.

In electroforming, special precautions are required for ensuring cleanliness of the solution, and since uniformity of deposit is of particular importance, special techniques are frequently employed, e.g., use of conforming anodes, bipolar electrodes, current-insulating shields and current robbers. Type of mandrel used depends on the shape of the article to be formed, and a range of materials may be used, a primary requisite being that they must be easily separable from the electroform when deposition is complete.

Among the established applications described in this article are (1) *metal screens*, electroformed of a core of copper surrounded by nickel, produced in fine meshes which are usually beyond the limits of production in perforated metal; (2) *reflectors*, consisting of copper and nickel electrodeposited on a master glass mould made conductive by a coating of silver, and coated, after separation, with a thin deposit of rhodium; (3) *injection-moulding cavities* for plastics, produced by electroforming of nickel. The peculiar advantages offered by electroformed nickel for such moulds are enumerated.

The Role of Nickel-Dip Treatment in Promoting Adherence of Enamels

G. C. DOUGLAS and J. M. ZANDER: 'X-Ray Diffraction Study of the Oxidation Characteristics of Nickel-Pickled Sheet Iron as Related to Enamel Adherence.' *Jnl. Amer. Ceramic Soc.*, 1951, vol. 34, Feb., pp. 52-9.

A highly detailed report is made of an extensive investigation designed to establish the effect of nickel pickling (nickel flashing) on (I) the oxidation of bare enamelling iron, and (II) the reactions occurring under ground-coat enamels. In the latter connexion two procedures were adopted for investigation, and were found to give concordant results.

From the data recorded, which are correlated with much of the relevant literature, the following conclusions are drawn:—

'(I) The investigations on oxidation of bare enamelling iron fired at 1250°-1550°F. (675°-842°C.) after pickling (1) without, and (2) with 0·11 g. nickel/sq. ft., show that nickel deposits decreased rate of oxidation at each of the temperatures used, and also favoured occurrence of the more highly oxidized oxides, so that even at 1550°F. Fe_3O_4 is still the predominant oxide. The results indicate that the nickel acts as a barrier at the iron surface, decreasing rate of oxidation by decreasing the availability of the iron.

'(II) The following processes involving oxides of iron take place during the firing of low- and high-temperature ground coat enamels.

'(1) (*a*) Both Fe_3O_4 and FeO form on the steel surface during the heat-up part of the firing cycle.

(*b*) After fusion of the enamel any Fe_3O_4 which has formed is converted to FeO.

(*c*) The oxide layer is taken into solution by the enamel. The rate of solution is high at first, but gradually decreases as the enamel becomes more nearly saturated.

'(2) Nickel pickling reduces the amount of oxide formed under the enamel. This reduction in the initial amount of oxide causes a correspondingly greater reduction in the time required for complete removal of the oxide.

'(3) With a typical high-temperature ground coat, the fact that nickel pickling favours adherence in a shorter time, or at a lower temperature, results primarily from the reduction in the initial amount of oxide.

'(4) In addition to controlling the initial oxidation, nickel pickling also contributes in another way to adherence development in the case of a typical low-temperature ground-coat enamel. This secondary effect probably results from the fact that the nickel decreases the rate at which the steel can be corroded by the enamel and prevents the formation of ferrous iron under certain conditions.

'(5) Two metallic phases, both of which are probably alloys, have been found at the enamel-iron interface. These metallic phases form slowly as the oxide layer dissolves, but they do not of themselves insure adherence. The precipitation of these metals does not take place in the absence of the cobalt, nickel and manganese oxides normally present in the ground coat.

'(6) Iron oxide smelted into a ground coat as Fe_3O_4 reduces the rate at which FeO can be dissolved during firing.

'(7) Although Fe_3O_4 adheres strongly to enamelling iron, no adherence seems to exist between FeO and iron.'

A theory is proposed in which it is assumed that adherence of ground-coat enamels to steel results from the sharing of oxygen atoms between the enamel and the steel. The enamel must first remove the initial oxide layer and then corrode the underlying steel in such a way that oxidizing conditions are continuously maintained at the enamel-steel interface. Solid oxides are not necessary for this bond.

NON-FERROUS ALLOYS

Nickel-Aluminium Equilibrium Diagram

H. GROEBER: 'Nickel-Aluminium System.' *Zeitsch. für Metallkunde*, 1950, vol. 41, Aug., pp. 282-3.

Diagram modified to take account of work published since the appearance of HANSEN'S 'Der Aufbau der Zweistofflegierungen' (1936). Notes are added on observations made by the various investigators, with reference to the nature of the phases present, and the physical properties of the alloys. A *bibliography* of 15 references gives direction to the original investigations on which the diagram is based.

Sigma Phase in Nickel-Vanadium Alloys

A. H. SULLY: 'Sigma Phase in Transitional Metal Alloys.' *Nature*, 1951, vol. 167, Mar. 3, pp. 365-6.

The writer gives a tabular summary of observations reported, to date, on the existence, in alloys containing transitional metals, of a phase isomorphous with the sigma phase of the iron-chromium system. Bibliographical reference is given to original work. This note further advances the theory proposed earlier by the writer and his colleagues, that the occurrence of sigma is determined by a critical electron-atom ratio, i.e., that sigma is an electron compound. Using a critical ratio of excess bonding electrons to atoms, which agrees closely with observations made on the alloys of aluminium with transitional metals, theory predicts the appearance of sigma phase in the iron-chromium, cobalt-chromium, nickel-chromium, iron-vanadium, cobalt-vanadium and nickel-vanadium systems. Predicted boundary limits are tabulated and are compared with observed boundaries which have been reported. It is noted that although the theory predicts the appearance of sigma phase in nickel-chromium alloys, it has not been observed in this series. It is suggested that the upper temperature limit for the phase, which varies from system to system, is for nickel-chromium so low that transformation does not occur in a reasonable period of time.

Production and Properties of Nickel-Oxide Films containing Lithium

See abstract on p. 69.

Nickel Additions in Copper-Base Alloys

J. S. VANICK: 'Nickel-Tin Bronzes.' *Foundry*, 1951, vol. 79, Feb., pp. 102-7.

Fourth of series of articles reviewing the influence of nickel additions in various types of bronze and brass. (For reference to earlier items see *Nickel Bulletin*, 1951, vol. 24, No. 3, p. 54.)

This instalment deals with the properties of the 'Ni-Vee' bronzes, a series based initially on the 5 per cent. nickel, 5 per cent. tin composition. For specific purposes, larger or smaller amounts of these two elements may be used, and in some of the Ni-Vee alloys lead and zinc are present. A simplified classification of the alloys covered is given in the table below, and the paper contains much tabular and other information on properties of alloys within these ranges, as determined by the author and by other investigators, to whose work bibliographical references are given. The influence of modifications of composition (within the respective ranges), heat-treatment, and other variables, is discussed.

Foremost among the engineering advantages of the Ni-Vee bronzes are easy castability, low shrinkage, pressure tightness, and fine grain, and the possibility of producing, economically, alloys having widely varying, but closely controllable, properties.

Cold Working of Non-Ferrous Alloys: Institute of Metals Symposium

'Symposium on Metallurgical Aspects of the Cold Working of Non-Ferrous Metals and Alloys.' *Jnl. Inst. Metals*, 1951, vol. 78, pp. 463-619; *Monthly Jnl.*, Jan., 1951.

Advance copies of papers for symposium presented at the Annual Meetings of the Institute, March, 1951.

M. COOK and T. LL. RICHARDS: 'Fundamental Aspects of the Cold Working of Metals,' pp. 463-82; *Paper* 1286.

This introductory paper deals essentially with the *nature of the internal or structural changes involved in cold plastic deformation*, not with the technological aspects of the subject. The aim of the authors has been to provide a background study, in the light of existing knowledge and concepts, of the mechanism of the changes which take place when metals and alloys are plastically deformed in the cold state, as occurs in the various manufacturing operations described in later papers in the symposium.

S. F. CHISHOLM: 'Lubricants for the Cold Working of Non-Ferrous Metals,' pp. 483-500: *Paper* 1287.

The processes of cold rolling, press drawing, tube

Simplified Classification of Nickel-Tin Bronzes

No.	Cu	Ni	Sn	Pb	Zn	Tensile Strength		Elongation	BHN
	%	%	%	%	%	p.s.i.	t.s.i.		
Ni-Vee	88	5	5	—	2	50,000	22·35	40	85
Ni-Vee-T	Same as Ni-Vee, Heat-Treated (b)					65,000	29·0	10	130
Ni-Vee-HT	Same as Ni-Vee, Heat-Treated (a)					85,000	37·95	10	180
A	88	1	10	—	2	40,000	17·85	18	—
Ni-Vee-L5Z5	80	5	5	5	5	40,000	17·85	20	80
Ni-Vee-L5Z5-HT	Same as Ni-Vee-L5Z5, Heat-Treated (b)					50,000	22·35	5	120
14	85	2·5	2·5	5	5	35,000	15·65	30	60
B	85	1	5	5	5	30,000	13·40	20	—
Ni-Vee-L10	80	5	5	10	—	35,000	15·65	10	80
Ni-Vee-L10-HT	Same as Ni-Vee-L10, Heat-Treated (b)					40,000	17·85	5	110
Ni-Vee-L20	70	5	5	20	—	25,000	11·15	10	70
Ni-Vee-L20-HT	Same as Ni-Vee-L20, Heat-Treated (b)					30,000	13·40	5	80
C	80	—	10	10	—	—	—	—	—

REMARKS

CONSTRUCTIONAL BRONZES : Suitable for gears, cams, valves, constructional castings, etc.
'G' Bronze, 88-10-2 Type, A.S.T.M. Specification B143-49T (See A).

PRESSURE CASTINGS : Suitable for pumps, valves, fittings, plumbing goods, etc.
Ounce Metal, 85-5-5-5, A.S.T.M. Specification B145-49T (See B).

LEADED BEARING BRONZES : Suitable for bearings, bushings, anti-friction metal, etc.
Also as acid-resisting bronze for corrosion-resistance in acids, mine water, sulphite paper plant, etc.
80-10-10 Type, A.S.T.M. Specification B22-49T (See C).

(a) = 1400°F. (760°C.) 6-10 hours; water quench; 600°F. (315°C.) temper for 6-10 hours.
(b) = Temper (only) 6-10 hours at 575°F. (302°C.).

drawing and wire drawing are discussed, from the point of view of the demands which they make on lubricants. Suitable types of lubricant are suggested for use in each of these operations, the recommendations being based on the combined experience of workers in this country and in U.S.A.

C. E. DAVIES: 'The Cold Rolling of Non-Ferrous Metals in Sheet and Strip Form,' pp. 501-36: *Paper* 1288.

A general review of recent progress in rolling practice is followed by a description of modern technique in the rolling of (1) copper and copper alloys, and (2) aluminium and its light alloys. This paper also embodies much information on American, as well as British, practice.

F. T. CLEAVER and H. J. MILLER: 'Wire-Drawing Technique and Equipment,' pp. 537-62; *Paper* 1289.

In an introductory section, the authors review the history of development of wire drawing in this country, from the earliest days. This review is followed by a detailed description of modern machines and practice, including tandem- and cone-type machines in which slipping of the wire occurs in drawing, and also the non-slip types. Die design, materials and maintenance, lubricants, speeds of drawing, reductions and other aspects of wire drawing are discussed, and a detailed account is given of current practice in the production of wire of copper, brass, bronze, and other copper alloys, and of aluminium and aluminium alloys. Defects liable to be encountered in wire drawing are reviewed, and current trends in the wire-drawing industry are considered.

J. D. JEVONS: 'The Deep Drawing and Pressing of Non-Ferrous Metals and Alloys,' pp. 563-618; *Paper* 1290.

As an introduction, the significance of the terms 'sheet and strip', and 'deep drawing and pressing' is discussed, and reference is made to the extensive literature of the subject. Methods which are employed for deep drawing and pressing are described.

Tool materials and drawing lubricants are then discussed. In the former category the advantages and limitations of sintered carbides, carbon and alloy steels, nitrided steel, chromium-plated steel, cast iron, rubber, and wood tools are considered. The applicability of the various types of lubricant are briefly reviewed with reference to four groups: straight mineral oils, fatty and compound oils, solutions and emulsions of soluble oils and soaps in water, and drawing compounds of proprietary origin.

Inter-stage annealing is described, with particular emphasis on faults commonly occurring under industrial working conditions, and the incidence of critical-strain crystal growth.

Methods which may be used to determine the deep-drawing properties of sheet metal are of three types:

(1) tests commonly applied to metal for other purposes, e.g., hardness and tensile tests, bend tests, chemical analysis, metallographic examination, and X-ray examination;

(2) tests which, although of a special character, do not attempt to imitate the action of a punch and die, e.g., tear-length, wedge-drawing, magnetic, and special tensile tests;

(3) special tests designed to simulate actual deep-drawing or pressing processes, e.g., cupping and true deep-drawing tests.

The relative advantages and limitations of each of these classes of test, and the information which can be derived from the results which they yield, are reviewed. In the author's opinion, a useful compromise for industrial testing of sheet lies in the regular application of the following four tests, made in the order given, and on a decreasing proportion of samples: hardness, Erichsen, metallographic examination, and tensile tests. The function of each of these tests, in the scheme proposed, is described, and the practical and economic utility of such a schedule is demonstrated.

The occurrence of season cracking in non-ferrous materials in press shops is discussed, with examples, and it is pointed out that whereas it was formerly believed that low-temperature stress-relief annealing was the only preventive of season-cracking in brass, it has recently been found that susceptibility can be much reduced by the addition of 1 per cent. of silicon to alpha brass. Consideration is also given to stretcher-strain marking.

The final section of the paper comprises a discussion of the behaviour, under deep-drawing and pressing, of metals and alloys commonly subjected to these operations: aluminium and aluminium-base alloys, copper, beryllium-copper, brass, nickel and nickel-base alloys (Monel, Inconel, cupro-nickel, nickel silver), zinc and silver.

NICKEL-IRON ALLOYS

Properties and Applications of High-Permeability Nickel-Iron Alloys

G. A. V. SOWTER: 'High-Permeability Magnetic Alloys.' *Proc. Instn. Electrical Engineers*, 1951, Part II, vol. 98, Feb., pp. 5-8.

Abstract of Chairman's Address to the Measurements Section of the Institution, Oct., 1950.

A summary of the development and application of these alloys. A curve, based on the work of various investigators, shows the magnetic and electrical properties of binary nickel-iron alloys over the entire range, indicating the particular interest of alloys at the 78, 50 and 36 per cent. nickel levels. The factors affecting the production and maintenance of the special properties of these alloys, and methods which have been introduced to improve such properties, are reviewed, with particular reference to addition of minor percentages of other elements (e.g., chromium, molybdenum, copper), avoidance of contamination during processing, heat-treatment in a magnetic field, and control of structure by cold-work and heat-treatment.

A table shows the compositions and magnetic properties of the following materials:—electrolytic iron; 36/64 nickel-iron; Permalloy B; Radiometal, Radiometal II, H.C.R. alloy, Deltamax, 5000Z, (50-50

types); Mumetal, Permalloy C and Supermalloy (containing about 76-79 per cent. nickel, with iron and controlled amounts of molybdenum, copper and manganese in varying proportions); Vanadium Permendur (cobalt-iron-vanadium alloy), and nickel.

Classification is made of electrical apparatus, operating in various frequency ranges, in which high-permeability nickel-iron alloys are used. Among the well-established uses of these alloys are communication equipment, including that used for carrier frequencies, audio-frequency apparatus for recording, reproducing and distribution purposes; radar; radio, and television. Extensive use is also made of their unusual properties in the operation of measuring instruments, and in a wide range of other specialized equipment.

Standard Methods of Analysis of Iron and Steel

'Methods for the Analysis of Iron and Steel.'
'Part 17, Titanium in Permanent Magnet Alloys.'
B.S. 1121: Part 17: 1951.

The standard covers two methods for determination of titanium in alloys of the following type: aluminium 5-15, nickel 7-35, cobalt 10-30, copper 0·5-8, titanium 3·0 max., per cent., iron remainder.

Method 1. *Gravimetric Finish.* Titanium is precipitated with cupferron from a solution of the alloy containing the iron in the ferrous condition. After ignition and fusion, iron, copper and traces of nickel, cobalt, etc., are removed from an alkaline tartrate solution with hydrogen sulphide. Finally, titanium is again precipitated with cupferron, ignited to oxide and weighed. The method is applicable to alloys containing up to 3 per cent. titanium; in this range reproducibility is $\pm 0{\cdot}03$ per cent. titanium.

Method 2. *Absorptiometric Finish.* Hydrogen peroxide is added to an oxidized solution of the alloy in a mixture of sulphuric and phosphoric acids. The light absorption of the yellow-coloured pertitanic acid thus produced is measured and is related to a calibration curve prepared under the same conditions as the assay. This procedure also is applicable to alloys containing up to 3 per cent. titanium. With a 0·5 g. sample and a 1 cm. cell the reproducibility is $\pm 0{\cdot}03$ per cent. titanium. With larger cells the reproducibility is improved.

'Part 18, Chromium in Ferro-Chromium.'
B.S. 1121: Part 18: 1951.

The method depends upon decomposition of the alloy by digestion with sulphuric acid, and fuming after addition of phosphoric acid. Chromium is determined by silver nitrate/ammonium persulphate oxidation, followed by titration with ferrous ammonium sulphate and standard dichromate, using barium diphenylamine sulphonate as indicator. The method is applicable up to 100 per cent. chromium; in the 60-70 per cent. chromium range reproducibility is $\pm 0{\cdot}25$ per cent. chromium. The procedure described is suitable for both high- and low-carbon grades of the usual commercial types of ferro-chromium alloy, but is not recommended for special types containing more than 4 per cent. of silicon.

Columnar-Crystal Nickel-containing Magnet Alloys

'The Latest Developments in Permanent Magnets.'
Edgar Allen News, 1951, vol. 29, Jan., pp. 757-8.

This is a short note on the process which has been achieved by the Permanent Magnet Association in improvement of magnet alloys during the period 1935-1950. The landmarks referred to are:—

1935. Alnico developed from Alni —$BH_{max.}$ $1{\cdot}7 \times 10^6$
1938. Development of anisotropic magnets, leading to
1940. Alcomax I —$BH_{max.}$ $3{\cdot}3 \times 10^6$
1940. Alcomax II —$BH_{max.}$ ($4{\cdot}3 \times 10^6$ to $5{\cdot}19 \times 10^6$) and other anisotropic magnets
1948. Niobium-bearing alloys, typified by
Alcomax III —$BH_{max.}$ ($4{\cdot}7 \times 10^6$ to $5{\cdot}3 \times 10^6$)
and
Alcomax IV —$BH_{max.}$ $4{\cdot}3 \times 10^6$, together with Hc 750 oersted
1950. Columnar-Crystal Magnets
$BH_{max.}$ ($7{\cdot}0 \times 10^6$ to $8{\cdot}0 \times 10^6$)

Properties typical of all the above-mentioned grades are tabulated. For the columnar-crystal types the properties shown in the Table below are claimed. It is emphasized that these magnets are not yet on the market, and that enquiries for them cannot yet be entertained.

Particulars are also given (see Table below) of experimental Hynico II magnets.

Material	Remanence, Gauss	$BH_{max.}$, Gauss Oersted $\times 10^6$	Corresponding Energy, Ergs/cc.	Coercive Force (Hc), Oersted
Alcomax III .. .. .. Fully columnar-crystal formation	13,500	7·0/8·0	278,000-318,000	745
Alcomax III .. .. Partial columnar-crystal formation	12,750	6·0/6·5	239,000-259,000	745
Hynico II	5,500	1·6	64,000	900

Nickel-containing Magnets in Coin-Operated Machines

W. A. PATZER: 'Coin-Operated Controls: Check for Spurious Coins.' *Machine Design*, 1951, vol. 23, Feb., pp. 141-5.

The article describes some of the counterfeit-coin-rejecting mechanisms designed by the author, which are covered by patents in many countries.

Magnets have proved to be the only inexpensive means of detecting metallic content, and are now extensively used. The first employed in the coin-operated machines were of the cobalt-steel type and were used to detect zinc, brass and copper slugs. These magnets proved unsatisfactory, however, due to loss of magnetism caused by shock and vibration. This problem was overcome by using an Alnico magnet, which also increased the effective action to such an extent as to make possible reduction in size of the magnet to one-third that required when cobalt steel was used. Alnico magnets only $\frac{3}{4}$ in. $\times \frac{5}{8}$ in. $\times \frac{5}{8}$ in. are found to create a sufficiently strong field for effective operation, and they have the further advantage of withstanding shocks involved in service and temperatures up to 600°F. (315°C.), without loss in efficiency.

Properties and Uses of Thermometals

HENRY WIGGIN AND CO., LTD.: 'Wilco-Wiggin Thermometal.' *Publn.* 372*; 1951, 45 pp.

Revised edition of Publication 104, 1947, containing practical reference data designed to facilitate correct and advantageous use of the wide range of thermostatic-control materials now available.

CAST IRON

Spheroidal-Graphite Cast Iron: Current Stage of Development

A. P. GAGNEBIN: 'The Industrial Status of Ductile Iron.' *Mechanical Engineering*, 1951, vol. 73, Feb., pp. 101-8.

This is essentially a review paper, taking stock of the current stage of development at the date at which it was presented at a Conference on Nodular Iron, held at Massachusetts Institute of Technology, Sept., 1950.

At the outset it is emphasized that ductile iron is no longer in the pilot-plant stage, but is now a fully-fledged engineering material, manufactured (by some 300 foundries in about a dozen countries) and purchased on the basis of specifications.

Four principal grades of this iron are in production, of which typical properties are shown in the table on p. 81.

Relationship between tensile strength, elongation and hardness normally found in the as-cast condition are illustrated by a figure given in the paper, and the structures characteristic of the irons in various conditions are shown by a series of photomicrographs. Specifications which have been proposed for the four grades of iron are listed; see *Nickel Bulletin*, 1950, vol. 23, No. 7, p. 131.

The magnesium process is applicable to a wide range of base irons, the broad compositions of which are tabulated, together with some other ranges of composition employed for specific applications. The functions of the respective basis elements are briefly discussed.

As an indication of the consistency with which the desired properties can be obtained in magnesium-treated cast irons, a figure is given illustrating the day-to-day production of a small foundry producing ductile cast iron to a specification of 90,000 p.s.i. (40·2 tons per sq. in.) minimum tensile strength and 2 per cent. elongation. The consistency of effect is further demonstrated by a record of tests (for 22 days) from keel bars corresponding to the 1st, 22nd and 50th castings from a 600-lb. ladle which was poured into 50 individual castings, over a period of 8 minutes. The variation of properties is small, and well within that normally to be anticipated from heat to heat.

Properties which render the new irons of particular interest are individually discussed in relation to typical applications in which such properties are especially utilized, e.g.,

- *pressure tightness* (utilized with advantage in pressure castings of various types),
- *high yield strength in combination with toughness* (useful in castings for agricultural implements, road machinery, mining and milling machinery, etc.),
- *wear-resistance* (as required in piston rings, cylinder liners, pistons, implement parts, etc.),
- *fatigue-resistance* (a quality used with advantage in castings for generator shafts and crankshafts),
- *abrasion-resistance combined with toughness* (utilized, for example, in plough points, excavating equipment, ore-chute liners, mining equipment and other castings),
- *heat-resistance* (as required in furnace doors, grate bars and other furnace castings, for which resistance to oxidation and growth is a primary requisite).

A further property which is of considerable interest is the good machinability of the magnesium-treated irons. A table showing some data from a comparative study of machinability of various ferrous and non-ferrous materials includes much interesting information. For example, a ductile iron, as-cast, having a tensile strength of 93,000 p.s.i. (41·5 tons per sq. in.) is shown to have machinability equal to that of grey cast iron having a tensile strength of 45,000 p.s.i. (20 tons per sq. in.). Again, attention is drawn to figures showing that ductile iron in the annealed condition, having a tensile strength of 70,000 p.s.i. (31·25 tons per sq. in.), and elongation of 22 per cent. can yet be machined at the rate of 960 ft. per minute, i.e., 2-3 times as quickly as good-quality grey cast iron.

The paper concludes with some examples of successful substitution of ductile cast iron for steel and for bronze. Further development of the new irons will still more fully demonstrate their economic value.

* *We shall be pleased to supply a free copy of this publication.*

Representative Mechanical Properties of Commercial Heats of Ductile Iron (*Abstract on p. 80*)

Grade	Tensile Strength	Yield Strength	Elongation %	Brinell Hardness No.	Usual Condition
90-65-02	95/105,000 p.s.i. 42·5/46·9 t.s.i.	70/75,000 p.s.i. 31·25/33·5 t.s.i.	2·5/5·5	225/265	As-cast
80-60-05	85/95,000 p.s.i. 37·9/42·5 t.s.i.	65/70,000 p.s.i. 29/31·25 t.s.i.	5·5/10·0	195/225	As-cast
60-45-15	65/75,000 p.s.i. 29/33·5 t.s.i.	50/60,000 p.s.i. 22·3/26·8 t.s.i.	17·0/23·0	140/180	Annealed
80-60-00	85/95,000 p.s.i. 37·9/42·5 t.s.i.	65/75,000 p.s.i. 29/33·5 t.s.i.	1·0/3·0	230/290	As-cast

Dilatometric Studies on Spheroidal-Graphite Cast Iron

N. A. ZIEGLER, W. L. MEINHART and J. R. GOLDSMITH: 'Dilatometer Studies of Nodular Cast Iron.' *Trans. Amer. Foundrymen's Assocn.*, 1950, vol. 58, pp. 637-48; disc., pp. 648-9.

In an introduction, the authors stress the importance of using a good-quality basis iron, of correctly controlled composition, if satisfactory results are to be obtained by magnesium treatment. In this connexion, the influence of carbon, sulphur and phosphorus is briefly considered. Experience has indicated that best results are obtained by using a nickel-magnesium alloy as the addition material. Copper-magnesium alloys react slowly with the molten iron and form heavy slag or oxide, which is difficult to remove; magnesium-bearing ferro-silicon (silicon 45, aluminium 2, magnesium 7-8, per cent., balance iron) was found to give inconsistent results. The possible advantages of magnesium-containing ferro-silicon, if it could be improved in reliability, are conceded.

The authors have found that by treatment of a basis cast iron of suitable composition with about 0·25 per cent. of magnesium (80-20 nickel-magnesium alloy), and inoculation with about 0·5 per cent. of silicon, a spheroidal-graphite cast iron can be produced which will consistently show the following properties: tensile strength 70,000-90,000 p.s.i. (31·25-40·2 tons per sq. in.), yield point 50,000-70,000 p.s.i. (22·3-31·25 tons per sq. in.), elongation 10-15 per cent., hardness 150-200 Brinell.

Particular attention is drawn to a characteristic of nodular- or spheroidal-graphite cast iron to which, it is considered, insufficient importance has been attributed, namely, that in cross-sections of about ½ in. to about 3 in. properties and structure are not affected by wall thickness. In sections below ½ in. the metal tends to become white and hard, and the amount and size of the graphite noduli decrease.

The work described in this paper was undertaken to determine more closely the effects occurring in castings which are partly of heavy and partly of light section. Compositions of the irons used are shown in the table below.

A step-type block (square steps 1, ½, ⅜, ¼, and ⅛-in. thick) was used as the experimental casting, and sets of five samples (one from each section of the step block) were subjected to three different dilatometer cycles, each of which was chosen with the primary object of studying graphitization of either primary cementite at temperatures above the transformation range, or of pearlitic carbides within the transformation range. The dilatometric curves are shown and the observations made are correlated with structure.

The following conclusions are drawn:—

Permanent growth produced by heat treating, and associated with complete (or almost complete) graphitization of combined carbon, in cross-sections of over ½ in., is uniform, and amounts to about 0·5 per cent. of linear dimensions. In thinner cross sections it rapidly increases, and in those of about ⅛ in. thick becomes as high as 1 per cent. or over.

Complete or almost complete graphitization of combined carbon is best achieved by a 'step-cycle annealing' treatment from 1740°F. (950°C.). At least a 2-hour holding period at 1740°F. (950°C.) is necessary to graphitize the primary cementite. This treatment should be followed by holding for 1½ hours in the range 1335°-1155°F. (723°-623°C.), and the holding period should preferably be divided into three stages. In heavy-walled castings a rather longer period may be required for this treatment. If some excess primary cementite remains after the high-temperature holding period, it is difficult to graphitize in the transformation range.

Heat-treatment of spheroidal-graphite cast iron should be regulated, to some extent, according to size of casting. Small, thin-walled castings should be

Si %	Mn %	S %	P %	TC %	Ni %	Mg %	Mo %	Cr %	Cu %
2·60	0·73	0·026	0·13	3·74	1·06	0·18	tr.	tr.	tr.
2·11	0·82	0·028	0·12	3·70	0·91	0·18	tr.	tr.	tr.

allowed longer time at the high temperature, but require less time within the transformation range, whereas heavy-walled castings, containing little or no excess carbide, require a shorter time at high temperature, but should be allowed ample time in the transformation range. For castings comprising both heavy and light sections, a compromise of these requirements must be made.

Annealing Characteristics of Spheroidal-Graphite Cast Iron

J. E. REHDER: 'An Introduction to the Annealing of Nodular Iron.' *Trans. Amer. Foundrymen's Assocn.*, 1950, vol. 58, pp. 298-308; disc., pp. 308-11.

In numerous applications of magnesium-treated cast irons the degree of ductility, resistance to impact, and machinability obtained by complete removal of pearlite and primary carbide from the matrix structure is of particular interest. Under suitable conditions, spheroidal-graphite cast irons can be produced with a ferritic matrix as cast, by ensuring complete decomposition of the pearlite and carbide during cooling of the casting in the mould, but the more usual method is to effect the ferritizing change by an annealing treatment after casting. The object of the work described in the present paper was a study of the process of decomposition of pearlite and primary carbide, the type of reactions involved, the order of times and temperatures necessary, and the effect, on mechanical properties of the irons, of removal of pearlite from the matrix. The work was done on irons into which the magnesium was introduced by means of (1) an iron-magnesium-silicon, and (2) a copper-magnesium, pre-alloy. The results obtained and conclusions drawn, see below, are believed to be generally applicable to nodular- and spheroidal-graphite cast irons.

Observations made indicate that 'the process and kinetics of the decomposition of primary and pearlitic cementite during the annealing of nodular iron are similar to those for the annealing of normal white cast irons and malleable irons, with the metallographic difference that the graphite precipitates in spherulitic, rather than flake-aggregate form'.

Differences found in the times required for annealing nodular- or spheroidal-graphite cast irons and malleable irons are believed to be explicable on the basis of differences in chemical composition, but at present no quantitative correlation has been found possible.

The last traces of cementite or pearlite in nodular irons containing magnesium are persistent, and are relatively slow to disappear. An unidentified non-metallic inclusion was found, in considerable amounts, in the cast irons used; it appeared to be a powerful carbide stabilizer.

As with malleable and grey cast irons, overall annealing time is reduced to a minimum by eliminating pearlite by slow cooling through the critical range, rather than by isothermal sub-critical annealing. Total annealing time necessary for treatment of nodular- or spheroidal-graphite cast iron is considerably shorter than that required for malleable iron.

The retarding influence of manganese, on rates of graphitization, is particularly obvious in the new irons, due to the very low sulphur contents. Low manganese is essential if annealing times are to be reduced to a minimum, and also if a ferritic structure is to be produced in the as-cast condition.

Presence of some pearlite in the matrix does not seriously lower the elongation obtained in nodular- or spheroidal-graphite irons, but maximum elongation and the optimum combination of properties are obtained with a completely ferritic structure.

Ni-Hard Plates for Crushing Industrial Diamonds

R. S. YOUNG: 'Crusher Plates for Diamonds.' *Jnl. of Metals*, 1951, vol. 191, Feb., p. 97.

Boart, the lowest-priced type of industrial diamond, is received by the distributing organizations in sizes ranging from 1 to 40 mm. diameter, and is broken up by jaw-crusher plates to give sizes below 2·8 mm.

Jaw plates of unalloyed iron have been found to wear so rapidly as to make replacement imperative after treating only about 50,000 carats. Further, the necessity of separating abraded iron from the diamond particles before sale made the operation a tedious one and uneconomic. Manganese-steel jaw plates gave longer life (some 900,000 carats), but due to the non-magnetic nature of the steel the abraded material could not be magnetically separated from the crushed diamond, and extra caratage had to be allowed to the purchaser in compensation for the steel content of the mass.

On the recommendation of the Diamond Research Laboratory, Ni-Hard crusher plates (chill-cast and stress-relieved) have been introduced, and after a year's working the service reports are highly satisfactory. Life obtained is slightly longer than that of the manganese steel (about 1,000,000 carats can be crushed before replacement is necessary), and the small quantity of Ni-Hard contained in the crushed mass can be removed by magnetic separation.

It is pointed out that this work represents the severest condition of operation known for crusher plates, as evidenced by the fact that even the 1,000,000 carats crushed in the life of the abrasion-resistant Ni-Hard crushers is only about 440 pounds.

Nickel-containing Steels and Cast Irons used in Gears

See abstract on p. 83.

CONSTRUCTIONAL STEELS

Influence of Alloy Elements on Transition Temperature of Steels

H. M. BANTA, R. H. FRAZIER and C. H. LORIG: 'Some Metallurgical Aspects of Ship Steel Quality.' *Welding Jnl.*, 1951, vol. 30, Feb., Suppl. pp. 79-89; disc., pp. 89-90.

Extensive research conducted under the auspices of the Ship Structure Committee of the American Welding Society has shown that the transition temperature of plate steel (the temperature at which the steel

changes from tough to brittle fracture) is closely paralleled by service performance of the steel in welded ship structures. Subsequent study has indicated that steels of nominally identical composition, processed under identical conditions, and having similar tensile properties, may differ widely in notched-bar impact properties.

This report contains the results of a laboratory research project, sponsored by the U.S. Bureau of Ships, with the object of determining the influence of chemical composition (within limits likely to occur in ship steel) and deoxidation procedure. The data show that transition temperature of steels of this type is progressively raised, to an appreciable extent, by increasing carbon, phosphorus and vanadium contents. Sulphur, in amounts commonly present in commercial steels, appears unlikely to have any significant effect in this connexion. With regard to silicon, conclusive evidence is not yet available, but within the range covered in the investigation (up to 0·09 per cent.) this element does not appear to raise the transition temperature. Increase in manganese (0·04-1·03 per cent.) definitely lowers the transition temperature, and it is also lowered, quite pronouncedly, by lowering the finishing temperature of the hot-rolled plate.

In discussion, J. W. HALLEY gave a table, compiled from the published results of various investigators, showing influence of each 0·10 per cent. of the following elements, on transition temperature: manganese nickel, phosphorus, vanadium, silicon. Nickel, as well as manganese, is shown to confer improvement in this respect.

Nickel-containing Steels and Cast Irons used in Gears

C. M. SCHWITTER: 'Some New Materials for Consideration as Gears.' Paper to Amer. Gear Manufacturers' Assocn., Oct., 1950; see also *Machinery* (*N.Y.*), 1950, vol. 57, Dec., pp. 179-82; 1951, vol. 58, Jan., pp. 181-3.

In 1939 the author presented, before the same Association, a paper containing a comprehensive review of nickel-containing materials used in gears. The 1950 paper deals more specifically with two materials: (1) Nitralloy 'N', a somewhat highly alloyed steel of the S.A.E. 4300 type, containing an addition of about 1·25 per cent. aluminium; (2) magnesium-treated spheroidal-graphite cast iron.

The mechanical properties of Nitralloy 'N', a typical composition of which is shown in Table I, are, in the quenched-and-tempered condition, parallel to those of S.A.E. 4340, and the annealing treatment required to put the steel into a condition of maximum machinability is of the usual type. Two procedures are recommended, both involving austenitizing at 1500°-1550°F. (815°-840°C.), followed by isothermal transformation, or continuous-cooling transformation. Details of the respective cycles are given. Both produce a hardness of about 217 Brinell, and a structure consisting of ferrite and fine carbide spheroids, with some pearlite.

The unique characteristic of Nitralloy 'N' to which special attention is directed is its capacity for precipitation hardening. The changes in properties producible in the precipitation-hardened steel are shown in Table II, in comparison with the characteristics of the steel in the quenched-and-tempered state.

Table I

Customary Chemical Limits for Nitralloy 'N'

	%
Carbon	0·20-0·27
Manganese	0·40-0·70
Nickel	3·25-3·75
Chromium	1·00-1·30
Molybdenum	0·20-0·30
Aluminium	1·10-1·40

Table II

Tensile Properties of Nitralloy 'N' Before and After Ageing

	Before Ageing: oil-quenched 1650°F.(898°C.) tempered 1200°F. (648°C.)	After Ageing: 48 hours at 975°F.(523°C.)*
Tensile Strength, p.s.i.	132,400	190,250
t.s.i.	54·6	84·9
Yield Point, p.s.i.	114,600	180,000
t.s.i.	51·2	80·4
Elongn., per cent. in 2 in.	22	15
Redn. of Area, per cent.	59	43
Brinell Hardness	277	415

* If a nitrided case is not required this treatment can be shortened. Values obtainable by shorter treatments are given in the paper.

Treatments other than quenching-and-tempering may be used as a preliminary to ageing, but the properties obtained after hardening are not so satisfactory as those of the quenched - and - tempered + precipitation-hardened steel. In particular, the impact values are not so high: the influence of varying the preliminary treatment, as influencing impact strength, is demonstrated.

Notch-sensitivity of Nitralloy 'N' is high in relation to that of S.A.E. 4340, but it is pointed out that this is a severe comparison, since the 4340 steel is generally recognized as being one of the best heavy-duty materials available, having excellent notch toughness at high strength levels.

With regard to distortion of Nitralloy 'N', it is noted that the steel reacts to quenching and tempering in the same way as any other heavily alloyed steel; final machining should be completed only after this preliminary cycle. Distortion resulting from precipitation hardening is practically negligible. When a nitrided case is produced, an allowance of about 0·001 in. per inch is made; the dimensional change, due almost entirely to absorption of nitrogen by the surface layers, is quite uniform. In absence of nitrogen, change in dimensions is negligible.

On the basis of the above observations, manufacturing cycles for Nitralloy 'N' gears are proposed:—preliminary oil-quench and temper, machining of the gear from the forged blank, ageing treatment, followed by finishing of the gear. If exceptionally high dimensional precision is required it may be advantageous only to rough-machine after the preliminary quench-and-temper treatment, interposing at that stage a stress-relief treatment at 1200°F. (648°C.), followed by finish-machining and ageing. In some cases a prior normalizing treatment at 1750°F. (953°C.) may be advisable,

to promote homogeneity. Maximum machinability plus maximum properties can be achieved by a combination of treatments, in cases where the added cost is justifiable. Where necessary, it is also possible to incorporate a nitriding cycle as the final ageing treatment, thus obtaining a Vickers hardness of about 950, with a total depth of case of about 0·02 in. Gears so treated show high resistance to wear, plus the unusually good combination of properties characteristic of core material of this composition.

The second part of the paper presents information on the properties of 'ductile cast iron'. The specifications which have been proposed by International Nickel Company for four grades of this iron are tabulated (cf. *Iron Age*, 1950, vol. 165, May 4, p. 89; *Nickel Bulletin*, 1950, vol. 23, No. 7, p. 131)*, and still further combinations of properties which can be obtained by modifications in heat-treatment are discussed and illustrated. In connexion with its suitability for gears and other constructional applications, attention is directed to the relative insensitivity of spheroidal-graphite cast iron to change in section, and it is indicated that work in progress is likely to ensure even more favourable developments in this respect. The ratio of compressive to tensile strength in ductile cast irons is midway between the values given by grey cast iron and by steel, and it also has an intermediate position as regards modulus of elasticity. A curve in the paper shows a comparison between the elastic characteristics of ductile iron and those of steel. The damping capacity of the spheroidal-graphite iron, while better than that of steel, is not so high as that of grey cast iron of low strength.

In considering properties in relation to the requirements of the designing engineer, the endurance characteristics of steel, spheroidal-graphite and grey cast iron are compared. In the form of polished bars, the new cast irons are somewhat inferior to steel, but the values of notched endurance limits, which are of more practical interest in this connexion, show a definite superiority for the spheroidal-graphite iron, in comparison with both steel and grey cast iron.

The improved toughness of the new irons is demonstrated by comparative data on plain, low-alloy and magnesium-treated cast irons over the range −300° to +70°F. (−184° to +21°C.), and further proof of the qualities of the material in this respect are provided by a comparison of results of notch-impact tests in both the as-cast and the heat-treated conditions.

A property of particular interest in connexion with gear service is resistance to wear, or to scoring or galling. Data are presented by the author indicating that ductile irons compare favourably in wear characteristics with the best open-grained cast iron made in statically cast pots for piston-ring purposes. Results of galling tests, also recorded in the paper, demonstrate that grey cast irons with coarse flake graphite are considerably more resistant to galling than irons containing fine, dendritic graphite. The ductile irons, of appreciably high strength, but not necessarily higher hardness, show about the same advantage in this respect as A.F.S. type A graphite irons.

Service data in wear-resisting applications are already available for the new cast irons; experience with ductile iron bearing halves in table rolls for a hot-sheet mill show that a service life four to five times that of bronze is obtained, at one-third the initial cost. A further service record, on two gear racks after a 1500-hour test run at 50 per cent. overload, operating against a gear of high-carbon sintered steel impregnated with copper, demonstrates the superiority of the ductile-iron rack in comparison with a rack of medium-manganese steel, with the added advantage of much saving in cost.

With regard to machinability, the author quotes the results of comprehensive investigation of comparative machinability recently reported by Curtiss Wright Corporation (see *Nickel Bulletin*, 1951, vol. 24, No. 1, p. 6). These tests proved the advantages of ductile iron, which are clearly evident in the as-cast condition, and are even more strikingly demonstrated in the annealed state. Results of a limited series of flame-hardening experiments have indicated that the ductile irons are satisfactorily susceptible to surface hardening by this method.

The author emphasizes that ductile cast irons are at present only in their infancy, and that their potential value in making possible the re-design of existing parts, and the development of new designs, is barely yet realized.

*See also this issue, p.81.

Surface Hardening of Steel: Processes, Properties of Treated Steels

G. T. COLEGATE: 'The Surface Hardening of Steel.' Part I. 'Methods and Practices.' *Metal Treatment and Drop Forging*, 1951, vol. 18, pp. 5-12.

Part II. 'Mechanism of the Carburizing Process and the Effect of Alloying and Heat Treatment.' *ibid.*, Feb., pp. 63-70. (Series to be continued.)

In this series it is proposed to survey past and present theories associated with the surface hardening of steel, and to describe modern practice.

Part I comprises an introductory résumé of case-hardening methods generally employed in industry. A chart shows the inter-relationship of the various surface-hardening methods, and a brief review is made of the essential features of the following processes; flame hardening, induction hardening, carburizing, nitriding, cyaniding, and some miscellaneous methods (e.g., dry cyaniding and Chapmanizing). Factors affecting choice of method for various applications are reviewed, in general terms, with some discussion of considerations involved in deciding on depth of case to be applied and the thickness of case required for specific applications. A summary is made of reasons which may dictate the selection of a surface-hardened steel for a particular use, and relationships between case and core which will ensure optimum service in case-hardened parts are discussed.

Part II opens with a discussion of the mechanism of the carburizing process, i.e., the mode of transfer of carbon to the outer layers of the steel. This is followed by consideration of the influence of the various alloy elements on carburizing properties of steel. Attention is directed to the rôle of nickel in toughening and increasing the strength of the core; of chromium in intensifying the hardness of the case;

of manganese in increasing hardness of case and rate of carburization, and of molybdenum, which also increases rate of carburization. The possible effect of impurities, as affecting carburizing characteristics, is also considered.

A table taken from a paper by Houdremont and Schrader shows the effect of individual elements on case depth and maximum carbon content attainable in carburizing. A further table lists compositions of steels generally used for case hardening.

Effect of grain size as a factor in achieving satisfactory properties in case-hardened steels is discussed, and the final section reviews heat-treatments applied before and after carburizing. In connexion with the post-carburizing treatments, the relative values of the double-quench, triple-quench, single-quench, re-quench and normalize, and re-quench treatments are reviewed, and the value of a final low-temperature stress-relief treatment is emphasized.

Carburizing of Steels: Recommended Practice

T. A. FRISCHMAN: 'Good Carburizing Practice.' *Machinist*, 1950, vol. 94, and 1951, vol. 95.

A practical series of articles, containing much useful information on equipment and technique, and on materials suitable for case-hardening by carburizing. The individual instalments cover:—

(1) The Carburizing Process and Pack Carburizing Compounds (Nov. 11, pp. 1615-19).
(2) Application of Pack and Gas Carburizing (Nov. 18, pp. 1666-70).
(3) Production of Carburizing and Carrier Gases (Jan. 6, pp. 19-21).
(4) Control Procedure in Gas Carburizing (Jan. 13, pp. 52-5).
(5) Liquid Salt-Bath Carburizing (Jan. 20, pp. 83-7).
(6) Selection of Steels for Production of Satisfactory Case and Core Properties, including table of composition of nickel-alloy steels of carburizing grades (Feb. 17, pp. 227-30).
(7) Selection of Case Depth and Treatments for Refinement of Case (Mar. 3, pp. 314-17).

The writer is the chief metallurgist, Axle Division, Eaton Manufacturing Company.

U.S. 'Tentative Standard Alternate' Steels

E. L. CADY: 'Alternate Steels Useful as Substitutes for Critical Materials.' *Materials and Methods*, 1951, vol. 33, Jan., pp. 62-3.

The article is written in connexion with orders recently issued by the National Production Authority with regard to conservation of strategic elements in steels (Order 32 A).

'Leaner-alloy' steels, developed during the war under the designation 'National Emergency' steels, proved to be more generally useful than was anticipated at the time of their introduction, but it is felt that full utilization of their properties and potential value at the present time is being restricted by the implications of the designation 'emergency'. It has therefore been decided that the grades now generally in use shall be re-named 'Tentative Standard'.

This article gives the following list of steels in the S.A.E. standard series, and of steels of the 'T.S.' group which may be considered as alternatives:

Standard Steel Series	Tentative Standard Alternates
1300	8600
2300	8600 (to 2330 inclusive) 8700 8600 plus 5 points carbon (for 2335 and higher) NOTE: For low-temperature applications, consider the possibility of using a heat-treated product.
2500	9300 (except for low-temperature and corrosive-condition applications)
3100	8600 (to 3130 inclusive) 8700 8600 plus 5 points carbon (for 3135 and higher)
3300	9300
4000	9700
4100	8600 (to 4130 inclusive) 8700 plus 5 points carbon (for 4132 and higher)
4300	No generally applicable alternate
4600	8600 (for bearings RBEC 4700 may be necessary)
4800	No generally applicable alternate
5000	Special low-alloy
5100	8600
52100	No generally applicable alternate
6100	8600
8600	No change
8700	No change
9200	8600
9300	No change
9400	8600
9700	No change
9800	No change

In addition, two more T.S. steels have recently been added: 4012, a chromium-molybdenum-manganese steel of carburizing grade, and 4720, the former RBEC 4720 (low-alloy nickel-chromium-molybdenum steel), which is believed to have wide potential usefulness.

It is pointed out that the additional knowledge of methods of control of composition and of modification of properties by heat-treatment, gained during and since the war, should make the problem of selecting alternative steels less difficult than in the 1939-45 period.

Standard Methods of Analysis of Iron and Steel

See abstract on p. 79.

HEAT- AND CORROSION-RESISTING ALLOYS

Properties of N-155 High-Temperature Alloy

W. O. BINDER: 'The Development of Low-Carbon N-155 Alloy for Gas-Turbine Construction.' *Jnl. Iron and Steel Inst.*, 1951, vol. 167, Feb., pp. 121-34.

The paper describes the alloy developed by Union Carbide and Carbon Research Laboratories, Inc., for

which the specification limits and nominal composition are shown in the table below.

	Specification Limits	Nominal Composition
Carbon	0·2 max.	0·12
Silicon	1 „	0·5
Manganese ..	1-2	1·5
Nickel	19-21	20
Chromium ..	20-22·5	20
Cobalt	18·5-21	20
Tungsten ..	2-3	2
Niobium ..	0·75-1·25*	1
Molybdenum ..	2·75-3·75	3
Nitrogen ..	0·1-0·2	0·12
Iron	Remainder	Remainder

*Current aeronautical materials specifications (S.A.E./A.M.S.) permit tantalum to be substituted in part for niobium.

Properties required in a wrought alloy which could be expected to give satisfactory service in the conditions obtaining in gas-turbine service were considered, with particular reference to turbo-supercharger-disc materials for operation at 650°C. Simultaneously the properties of materials requisite in alloys for use at temperatures up to 870°C. were also reviewed. Based on the conclusions reached in this review, the company planned a programme of research designed to develop an alloy which (1) should contain a major proportion of iron, (2) should not become excessively brittle after extended periods at elevated temperatures, (3) should be adaptable to work-hardening processes, and (4) should be capable of forming precipitation-hardening systems in which improved hot strength could be developed. A detailed description of some of the early work under this project is given in National Advisory Committee for Aeronautics Report ACR 3D28, 1943. The present paper gives the composition of alloys selected on the basis of the initial experiments, as worthy of further study (Alloys N-153, -154, -155 and -156). Considerations which dictated the ultimate choice of composition of N-155 are briefly reviewed, with particular reference to the lowering of the carbon content to the limits now specified. The effects of varying carbon are demonstrated by tabular data.

The remainder of the paper deals, in considerable detail, with the properties of the selected alloy. Much factual information is given, on physical and mechanical properties (at room temperature as well as at service temperatures), heat-treatment, structure, and fabricating qualities.

The data presented include a study of the influence of hot-cold working, solution treatment and precipitation-hardening treatments, on structure, strength at room temperature, and impact resistance. Properties at elevated temperatures are dealt with in detail, as affected by processing and other variables. The paper includes creep curves for various stresses at 650°, 730° and 815°C; in some cases results for periods as long as 10,000-32,000 hours are given. Scatter observed in stress-rupture test data is subjected to statistical analysis.

An outstanding feature is the important effect of previous fabricating treatment on the properties of N-155. Hot-cold working improves hot strength at temperatures up to 650°C., but in order to ensure uniformity of results it is recommended that this treatment should be preceded by solution treatment at 1060°-1150°C. If the service temperature at which high strength is required is above 650°C. it is preferable to subject the alloy to a solution treatment at 1090°-1230°C., followed by rapid cooling.

In general practice precipitation-hardening treatment is not applied to N-155, but under certain conditions such treatment may be beneficial in improving hot-ductility, removing stresses and giving an increase in yield strength. The author expresses the view that the combination of properties made available by ageing offers an interesting field of further investigation in connexion with this type of alloy. It is noted that no evidence of sigma phase was observed after ageing at either 730° or 815°C.

Properties of low-carbon N-155 in sheet form do not differ appreciably from those of bar stock and the forming qualities of the alloy are comparable to those of niobium-stabilized 18-8 chromium-nickel steel.

The combination of mechanical and physical properties characteristic of the alloy indicates its general suitability for high-temperature service, and the high chromium content gives assurance of adequate resistance to oxidation.

Plasticity and Creep: A.S.T.M. Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Plasticity and Creep of Metals.'
A.S.T.M. Special Tech. Publn. 107, 1950; 68 pp.

Reprint of papers and discussion presented during the Annual Meeting of the Society, June, 1949.

Introduction by J. E. DORN was followed by the papers shown below:—

L. R. JACKSON and W. T. LANKFORD: 'The Experimental Exploration of Plastic Flow in Sheet Metals', pp. 3-12; disc., pp. 13-17.

This report presents data on plastic flow in three materials, (1) a typical deep-drawing ferritic steel treated to ensure absence of a sharp yield point; (2) a ductile low-carbon rimmed steel which deforms in well-developed Lüder bands (designated 'Vitrenamel'); (3) copper, representative of a non-ferrous sheet metal. Plastic-flow curves are shown in the range from a strain of about 0·03 to the value of the maximum load, and results are given of bulge tests, designed to study the effects of biaxial tension. The results are interpreted as indicating that 'when anisotropy in real materials is taken into account, some of the current theory appears to correlate flow results very well, both in accounting for the stress required to maintain flow and in describing the distribution of strain resulting from various stress systems.'

W. SCHROEDER: 'Forming Parameters and Criteria for Design and Production,' pp. 18-36.

Results of some of the most significant investigations are reviewed, and the following aspects of the subject are specifically discussed: generalized stress and strain; dimensional similarity; laws of fracture; classification of formed sheet-metal parts; basic types of forming action (including stretching, bending and drawing); significant parameters and criteria for these three types of forming.

H. C. CROSS and L. R. JACKSON: 'The Use of Creep Data in Design.' pp. 37-47; disc., pp. 48-9.

The authors critically discuss the types of high-temperature data now available to the designing engineer, their limitations, the way in which they should be interpreted in design, and precautions which must be observed in interpolation or extrapolation of data beyond the range covered by actual experimental determination. It is shown, by examples relating to high-temperature materials, that extrapolations beyond actual test conditions are frequently unreliable. Much work is still required to put high-temperature design on a sound basis.

The literature relevant to this aspect of high-temperature work is reviewed, and examples illustrating the points discussed are provided by reference to the properties of typical alloys developed for high-temperature service, e.g., X-40, and S-816.

J. W. FREEMAN, D. N. FREY, E. E. REYNOLDS and A. E. WHITE: 'Super Creep-Resistant Alloys,' pp. 50-68.

Factors controlling the creep- and rupture-strengths of 'superalloys' are reviewed. From a compositional standpoint, the materials are considered in five groups:

(1) Modified austenitic steels containing various combinations of molybdenum, tungsten, niobium and titanium.

(2) Chromium-nickel-iron- and chromium-nickel-base alloys containing titanium and aluminium as precipitation-hardening agents. In these alloys, niobium and molybdenum have also been used.

(3) Cobalt-chromium-base alloys containing substantial additions of molybdenum, tungsten and niobium. Nickel has, in some cases, been substituted for part of the cobalt.

(4) Experimental alloys in which elements such as carbon, manganese, tantalum and boron have been added to increase creep strength.

(5) High-melting-point alloys, e.g., of chromium base. These are at present experimental only, due to lack of certain properties essential in high-temperature materials.

The importance of the inter-relationship between chemical composition, prior processing, and response to final treatments is demonstrated, as affecting the properties obtainable in the respective classes of alloy shown above; the properties of typical alloys of the respective grades are reported as a function of the variables mentioned, and theoretical concepts of the creep-resistance and other properties characteristic of high-temperature alloys are discussed. From the theoretical standpoint, it is considered that the major considerations are the modification of the basis strength of the matrix by (1) cold work or mechanical deformation of the matrix lattice, (2) the presence of an additional phase or phases, (3) the presence of grain boundaries. The influence of these variables, as demonstrated by the properties of known alloys, is reviewed.

Creep Testing of High-Temperature Alloys

H. V. KINSEY: 'An Evaluation of the Effective Gage-Length Equivalent of the Fillet and Shoulder of the Gage Length Portion of a Tension Test Bar under Creep and Stress-Rupture Conditions.'
A.S.T.M. Bull., 1951, No. 171, Jan., pp. 60-2.

Errors introduced into creep measurements when the overall test specimen (gauge length, fillets, shoulder) is included in the extensometer system are examined. Data on three high-temperature alloys (Inconel 'X' at 1500°F. (815°C.); S-816 at 1350° and 1500°F. (734° and 815°C.), and 73-J at 1500°F. (815°C.), are presented as examples to illustrate the arguments advanced.

It is shown that it is not possible to arrive at a common correction factor for the equivalent gauge length even for one alloy, if the true effective gauge length is to be known within limits of ± 1 per cent., unless a test specimen having an 8-in. gauge length is employed.

Nickel-containing Materials in the 'Auris' Gas Turbine

'Gas-Turbine Alternator Propulsive Machinery for Tanker 'Auris'.' *Engineering*, 1951, vol. 171, Feb. 23, pp. 209-12, 224.'

A detailed account of the gas-turbine alternator set designed and constructed by the British Thomson-Houston Company for installation in the oil-tanker 'Auris' (built for the Anglo-Saxon Petroleum Company in 1948, by Messrs. Hawthorn Leslie and Company). Heat- and corrosion-resisting nickel-containing steels and alloys have been extensively used in this unit: particulars are given of the components for which, respectively, Staybrite FCB, R. ex 326F and 337A, Immaculate 5, and Staybrite FDP have been selected. Design of the unit, and its operation, are well illustrated.

Nickel Alloys in the Glass Industry

'Nickel Alloys in Glass and Pottery Production.' *Ceramics*, 1951, vol. 23, Jan., pp. 606-8.

This brief article describes some typical uses of high-nickel alloys:

(1) Nimonic D (nickel-chromium-iron alloy), in general use for conveyors working under oxidizing or reducing conditions at temperatures up to about 1000°C., above which 80-20 nickel-chromium is to be preferred.

(2) Inconel glass-gathering and blowing irons, where the resistance of the alloy to oxidation under working conditions is an important asset in preventing discoloration of the glass being processed.

(3) Inconel electrodes in electronic devices used to

safeguard gas- and oil-fired apparatus, and to prevent explosions in combustion chambers and kilns employed in the ceramic industries.

Influence of Nickel on Stability of Structure in Austenitic Nickel-Chromium Steels

P. BASTIEN and J. DEDIEU: 'Effects Produced by Cold Work and Annealing in Low-Carbon 18-8 (Chromium-Nickel) Steel.' *Métaux et Corrosion*, 1950, vol. 26, Dec., pp. 308-11.

The authors report observations made during study of steels containing 18 per cent. of chromium, with nickel varying between 4 and 12 per cent., on which determinations were made of the proportion of alpha phase formed by cold working. The results have shown clearly marked differences in steels of only slightly different composition, and have confirmed the preponderant effect of nickel in favouring gamma-, and inhibiting alpha-, formation.

The note now published relates specifically to two steels of the following compositions:—

	C %	Cr %	Ni %
I	0·035	18·3	10
II	0·040	17·8	9

After 70 per cent. reduction by cold work Steel I remained in the stable, completely gamma, condition, whereas in Steel II 80 per cent. of alpha phase was observed. Comparative data on the work-hardening capacity of the two steels showed less tendency to hardening in the stable (No. I) steel.

Low-temperature annealing experiments on the two cold-worked steels showed that in Steel II sigma phase may be produced by such treatments.

German and American Stainless Steels: Comparative Review

C. A. ZAPFFE: 'German and American Stainless Compared.' *Iron Age*, 1951, vol. 167, Jan. 25, pp. 56-60.

The comparison is based on a standard list issued in Germany in April 1949 and the steels standard in U.S.A. at the same date. Tables show German designations and compositions, with A.I.S.I. equivalents (where existing), for the martensitic, ferritic and austenitic classes of steel. Comments are made on points of similarity and difference.

Among the aspects of specification and application to which special attention is drawn are the following:

Wartime introduction of manganese and nitrogen, in partial replacement of nickel, has not persisted to any important degree in the post-war German specifications. The percentages of nickel specified in the 1949 steels still reflect some shortage of this metal, although in the austenitic grades where stabilization is an important factor specification limits are more liberal.

Minor manganese contents tend to be higher in the U.S. than in the German steels, due mainly to American preference for manganese as improving hot-working characteristics, coupled with its slightly austenitizing influence.

Stabilizing practice for the austenitic steels varies in the two countries. In Germany, tantalum, as well as titanium and niobium, is used; ferritic steels are also frequently stabilized. Carbon contents of the German stabilized steels tend to be higher than in American practice, and the German specifications show lower ratios of titanium or niobium to carbon. In Germany stabilization heat-treatments are rarely used.

A greater preference is found in Germany than in America for the presence of a proportion of ferrite as a preventive of sensitization: the reasons for American hesitancy to utilize this method are briefly summarized.

Molybdenum is much more widely used in Germany than in America, being added to various steels in all the three classes reviewed, although in some cases molybdenum-bearing steels employed in America show higher contents of this element than German counterparts. Development of free-machining grades has progressed much farther in America than in Germany, where only sulphur appears to be used as a free-machining addition. The straight-chromium grades show relatively wide divergence of composition in the two countries.

The highly-work-hardening 17-7 chromium-nickel steel, which has been fairly generally used in America for higher-strength applications, is not used to any extent in Germany. In general, their austenitic steel specifications show, vis-à-vis the U.S. grades, a greater restriction in the carbon, chromium and nickel limits, a lower silicon content, and considerably lower manganese. One of the newer German grades closely resembles the U.S. type 304 (extra-low-carbon) grade. The free-spinning composition used in America (nickel 10-13 per cent.) has no parallel in German specifications.

Two special austenitic steel grades in use in Germany have no counterpart in American specifications; these are the 12-12 chromium-nickel grade and the 18-10 manganese-chromium type. The latter is the only high-manganese steel in the German post-war schedules. Their austenitic steel specifications also show a chromium-nickel steel containing molybdenum and copper, somewhat parallel to Carpenter No. 20, except that the German steel has a lower nickel content (18 per cent.).

Notes are added on recent German work and views on measurement of activation and passivation, and on causes and prevention of stress-corrosion cracking.

Processing of Austenitic Stainless Steel at Sub-Zero Temperatures

V. N. KRIVOBOK and A. M. TALBOT: 'Effect of Temperatures on the Mechanical Properties, Characteristics, and Processing of Austenitic Stainless Steels.' *Proc. Amer. Soc. Testing Materials*, 1950, vol. 50; Reprint of paper and discussion presented at the Annual Meeting of the Society, June, 1950; 36 pp.

Previous investigations on the influence of sub-zero temperatures on austenitic stainless steels have comprised tests at room temperature of steels previously exposed, for varying periods, to sub-zero temperatures. Results reported by various investigators agree

in showing that such exposure does not adversely affect the room-temperature properties of the steels, indicating that the composition is such as to ensure retention of metastable austenite over a wide range of temperature. Other investigations have been concerned with the effect of mechanical working (at room temperature) on the stability of structure.

The experiments reported in the present paper were planned to determine the effect of *simultaneous exposure to sub-zero temperature* (down to −320°F.: −196°C.) *and mechanical working*. The method adopted was rolling of sheet and drawing of wire while the material was at sub-zero temperature.

Steels of Types 301, 302, 304, 347 and 310 were variously processed; in most cases more than one initial condition was represented. Comparison was made among specimens of the steels rolled at room temperature, at −105°F. (−76°C.), and at −320°F. (−196°C.).

Conclusions which may be drawn from results of subsequent tests on the steels so treated, reported in extenso, are briefly summarized below:—

Mechanical working at the sub-zero temperatures induces a greater degree of work-hardening, with correspondingly increased tensile strength, yield strength and hardness, as compared with similar steels processed at room temperature. At a given value of tensile strength, ductility (elongation) of the sub-zero-processed steels is better than that of steels normally processed.

Processing at sub-zero temperatures widens the spread between tensile strength and yield strength.

Any desired level of tensile strength is produced by a smaller degree of reduction, either in rolling or drawing, by processing at sub-zero temperature.

Ageing, or low-temperature heat-treatment, enhances certain mechanical properties of the steels after sub-zero mechanical working; the degree of the effect so attainable depends on the composition of the steel treated.

All the steels tested, whether annealed or cold-rolled, show higher strength at sub-zero than at room temperatures. Cold-rolled steels, whether rolled at room temperatures or at sub-zero temperatures, have better ductility at sub-zero temperatures than at room temperature.

Distribution of ductility over a 2-in. gauge length is entirely different at sub-zero temperatures from that found at room temperature, and this difference in distribution permits easier fabrication by some forming processes if carried out at sub-normal temperatures. The practical significance of this observation was emphasized, both by the authors and by contributors to the discussion.

Exposure of quench-annealed, room-temperature cold-worked and sub-zero-rolled steels at 300°, 500°, 800° and 1000°F. (149°, 260°, 426° and 538°C.) showed that 'cold-rolled' steels do not suffer any adverse change in room-temperature properties even after considerable time at temperatures up to 800°F. (426°C.). Tensile properties, as well as ductility, of 'cold-rolled' stainless steels at elevated temperatures up to 800°F. are lower than the values at room temperature.

Production and Processing of Stainless-Steel Sheet and Strip

'Stainless Steels. Modern Electrical Applications to Strip and Sheet Production.' *Electrical Rev.*, 1951, vol. 148, Mar. 9, pp. 471-7.

An illustrated description of the electrical equipment used in various stages of production of nickel-chromium stainless-steel strip and sheet at the works of Samuel Fox and Company, Ltd., Stocksbridge. A step-by-step account is given of the various operations involved, from melting of the steel to finishing of the products.

Descaling and Pickling of Stainless Steels: Recommended Procedure

L. F. SPENCER: 'Scale Removal Technique with the Stainless Steels.' *Steel Processing*, 1950, vol. 36, Dec., pp. 623-8; 1951, vol. 37, Jan., pp. 28-30.

These articles are essentially a continuation of the series on cold working of stainless steels, published by the same author in *Steel Processing* during 1950; see *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 45. They describe treatments suitable for scale removal from stainless steels which are to be subjected to cold-working operations.

After brief reference to mechanical methods of scale removal, detailed consideration is given to chemical de-scaling and pickling solutions and technique. The compositions are given of eleven solutions which have been found satisfactory for use under various conditions, and their particular spheres of application are discussed. Recommendations are also made with regard to tank equipment for holding the various solutions recommended.

The second part of the article deals specifically with experience gained during the operation of a ferric sulphate/hydrofluoric acid pickling bath, which the author has found particularly useful. This pickle provides a one-bath scale-removal treatment, and the solution has the great advantage that it can be operated without a fume hood, since the reactions involved appear to be harmful neither to personnel nor surrounding equipment. Composition of the bath, which is patented by E. I. du Pont de Nemours and Co., Inc., is given as commercial ferric sulphate 6-8 per cent., hydrofluoric acid 1·8-2 per cent., balance water. It is operated at 160°-180°F. (70°-83°C.). Recommendations on operation, and methods for analysis of the bath for control purposes, are detailed.

The final section of the article gives a short note on passivation treatment of stainless steels, using a 10-20 per cent. nitric-acid solution, at room temperature to 140°F. (60°C.).

Commercial Electropolishing of Stainless Steel

F. G. BRUNE: 'Practical Electropolishing of Stainless Steel.' *Metal Finishing*, 1951, vol. 48, Oct., pp. 57-62, 112.

This eminently practical article is concerned solely with a discussion of 'procedures used in bringing electropolishing to a successful operation for continuous use in production finishing'. It is based on

experience in the shops of Marion Industries Division of Motor Products Corporation, Marion, O.

After trial of various solutions the decision was reached to standardize on the sulphuric-phosphoric acid bath, as developed by Battelle Memorial Institute. This procedure was found to satisfy the requirements laid down that (1) the finish produced must be satisfactory to customers, (2) the bath must be capable of polishing both straight-chromium and chromium-nickel steels, (3) the utmost simplicity of operation, compatible with efficiency, must be ensured.

This article gives an account of work done and conclusions reached with regard to limiting iron concentration permissible in the bath, and methods for analysis and control. Relationship between the nature of the stainless steels being polished and the polishing results is also considered, with particular reference to the influence of the mill finish on the steel. In this latter connexion the following conclusions were drawn with regard to three major defects tending to appear on electropolished steel:—

Pitting may be caused by electropolishing at too low a current density or with poor current distribution. The steel itself may be responsible for the defect if it contains non-metallic inclusions, is over-pickled, or is not cleaned before finishing.

Orange peel is caused by too large a grain size, with random orientation, or by grain-boundary precipitation of carbides.

Lines are due to grinding or drag polishing at the mill, rolling seams, and, occasionally, strain lines.

Poor lustre is caused by a combination of the above defects, and, in addition, may be due to the existence of complex carbides which do not electropolish at the same rate as the austenitic matrix.

A fine, homogeneous structure, free from non-metallic inclusions, rolling seams or precipitated carbides, will give best results, and in mill processing the pickling and the heat-treatment cycles, in relation to amount of reduction during cold passes, are important factors.

It was found that anode current efficiency falls from an average of 56 per cent. to 23 per cent. when the iron concentration is increased from 0·5 per cent. to 4·5 per cent. The voltage required depends on current density and on iron concentration. At 200 amp./sq. ft. an increase from 2·0 to 4·5 per cent. iron requires an increase of 4 volt. At 350 amp./sq. ft. the same change in iron content requires an increase of 7 volt.

In order to produce a commercial finish with all parts of approximately equal lustre, the bath must be operated within a certain iron-concentration range. Charts for calculation of correct operating conditions are given in the paper. As the iron content of the bath increases, it is normally desirable to increase the temperature of operation, and to lower the current density.

Work to be polished should be thoroughly cleaned before being placed in the tank; much trouble can be caused by scale on the metal, drawing compounds, or oils, acid flux left from soldering, and salts left on the steel from salt-bath treatment. For removal of salts after processing and to clean after electropolishing, the following cycle is recommended:—

Cold rinse, acid dip (10 per cent. H_2SO_4/1 per cent. $Na_2Cr_2O_7$); cold rinse; hot rinse; air dry.

Rate of working of the bath is known to be an important factor in control, but exact conditions for optimum working have not yet been theoretically established.

Steel tanks lined with chemical lead and then lined with acid-proof brick or tile are recommended for permanent installations. With the high currents used, it is considered that the electrical insulation provided by brick is essential. An automatic temperature-control system should be used, and tank capacity should be carefully considered. In general, the solution should operate at less than 5 amp./gall., which necessitates having sufficient space available for cathodes to operate at 20 per cent. of the anode current density. Fairly rapid mechanical agitation (50-80 ft./min.) in a horizontal direction is usually necessary, in order to prevent gas streaks, but parts having simple surface contour, and wire goods, can often be still polished. It is possible to use air agitation, but it is recommended only for mixing and cooling the solution.

Type 316 stainless-steel cathodes are preferred to lead cathodes because (1) the cost of equipping the tank is less than with lead; (2) the tank can be operated at a lower voltage; (3) the stainless steel requires little cleaning (by comparison with heavy sludging with lead cathodes), and little or no repair.

High currents employed make racks a difficult problem. Copper is passivated by the electropolishing current in the bath, and bare racks can therefore be used with fairly long spline life, but bare-rack points have a limited life at the contact area. Coating with speculum or tin has been found effective for prolonging life, but these materials do not completely passivate, with the result that the area employed increases the operating current required. Use of tantalum contact points is a further possibility, but is not an entirely economic proposition.

Stainless-Steel Castings in the Paper Industry

N. S. MOTT: 'Stainless Steel Castings, Valves and Fittings Beat Corrosion in Paper Industry.' *Paper Trade Jnl.*, 1951, vol. 132, Jan. 26, pp. 31-2, 34, 36.

The paper contains a condensed discussion of the corrosion problems arising in groundwood, soda, sulphate, and sulphite mills, and in chlorine bleaching. Mechanical, physical and corrosion-resisting properties of cast materials suitable for use in the respective sections are tabulated. The alloys discussed include various grades of the 18-8 chromium-nickel type, and higher-alloy austenitic alloys, modified with addition of molybdenum, niobium and copper; Hastelloy C; Monel and 'S' Monel; nickel.

Nickel Plating as Protection against Solder Attack

M. D. JEPSON: 'The Effect of Isothermal Treatment on the Mechanical Properties of Steel, with a Note on Solder Embrittlement.' *Metallurgia*, 1951, vol. 43, Feb., pp. 62-4, 81-2.

Comparison is made of the mechanical properties of patented steel wire* in four conditions, as produced,

**Carbon 0·84, silicon 0·22, manganese 0·53, phosphorus 0·033, sulphur 0·049, nickel 0·12, chromium 0·09, copper 0·12, per cent.*

respectively, by the following treatments:—

(1) water quenching, and tempering at 150°-600°C.;
(2) oil-quenching, and tempering within the same range;
(3) isothermal transformation at temperatures within the range 150°-600°C.;
(4) isothermal transformation at temperatures within the range 150°-400°C., followed by tempering at 400°-600°C.

Results of tensile tests were, in the main, unsatisfactory, for reasons which are given in the paper. These data were, therefore, not used as the basis for conclusions, which are drawn solely from the results of bend and hardness tests. The information obtained from the tests is considered to indicate the marked advantage of isothermal heat-treatment, as compared with the more conventional quench-and-temper treatments, in so far as the particular steel is concerned, and in the conditions of test used.

Low notch-toughness after quenching and tempering at temperatures below 300°C. was associated with numerous fine, radial cracks, present near the surface only. The effect was traced to embrittlement caused by attack of the molten solder of the tempering bath. In supplementary tests on embrittlement of steel under stress during immersion in molten solder it was observed that coating with nickel gave virtually complete protection, at least up to stresses of the order of 20 tons per sq. in. Copper-plated steel under stress was, however, highly susceptible to attack by the molten solder.

Properties of Silicon-containing Stainless-Steel Powder

A. H. GROBE and G. A. ROBERTS: 'Mechanical Properties of Stainless Steel Powder.' *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1951, vol. 191, pp. 125-30; *Tech. Paper* 3007 E; *Jnl. of Metals*, Feb., 1951.

Earlier attempts to produce nickel-chromium stainless-steel powder have shown that such material requires excessively high sintering temperatures, and that the properties obtainable are not as high as is desirable. This paper reports experiments which have proved that much more satisfactory properties can be obtained in an 18-8 steel containing about 2·5 per cent. silicon. A detailed report is made of tests using four blends of powder of different mesh, on which determinations were made of apparent density, flow rate, compression ratio, and pressing and sintering characteristics. Mechanical properties of pressed and sintered compacts were compared with those of wrought steel of the same composition. Sintering temperatures varied within the range 2100°-2350°F. (1149°-1286°C.); in most cases the time of treatment was 45 minutes. Compacting and coining pressures were in the range 30-50 tons per sq. in.

The results of the respective series of tests (reported in extenso) show that steel powder of the composition given is readily mouldable, that it can be sintered in hydrogen at temperatures as low as 2100°F. and that it yields compacts with higher strength and ductility values than have hitherto been attainable in stainless-steel parts produced from powders. The powder is free-flowing, and has an apparent density of 2·9 g. per c.c. amd a maximum weight loss, in hydrogen, of 0·35 per cent.

Optimum pressing and sintering temperatures varied with the size of powder; the finer ones can be handled at slightly lower pressures and temperatures than are necessary for those of larger size. A −100 mesh powder pressed at 40 tons per sq. in., and sintered for 45 minutes at 2250°F. (1231°C.) gave a tensile strength of 40,000 p.s.i. (17·9 tons per sq. in.), with elongation of 15 per cent., and coining at 40 tons and re-sintering for 45 minutes at the same temperature raised the tensile strength to 65,000 p.s.i. (29·05 tons per sq. in.), and the elongation to 22 per cent. The highest properties obtained with this powder, with compacting and coining pressures of 50 tons per sq. in. and sintering and re-sintering for 300 minutes each at 2250°F. (1231°C.) were 87,500 p.s.i. (39·09 tons per sq. in.) and 32 per cent. elongation. In a specially fine powder (−100 mesh with 62 per cent. of −325 mesh) values as high as 92,000 p.s.i. (41·08 tons per sq. in.) and 38 per cent. elongation were produced by compacting and coining under 50 tons pressure and sintering at 2350°F. (1286°C.).

The silicon constituent in the powder promotes the formation of a small amount of ferrite when high sintering temperatures are used, but it is considered that this would not seriously impair the corrosion-resistance of the material. Comparison of the properties of the powder-metallurgy specimens with those of wrought stainless steel showed that, under optimum conditions of pressing and sintering, properties almost equal to those of wrought material can be obtained. Ductility is, as would be anticipated, relatively lower in the powder-produced steel, and could be increased only by raising the density by means of extra cold-coining and sintering, or hot-coining treatments.

PATENTS

Extraction of Nickel from Lean Ores

In a process for the recovery of nickel from low-grade ores such as garnierite, the ore is treated with ammonium sulphate at about 400°C., and the product formed is treated with an aqueous solution of ammonium hydroxide and ammonium carbonate. The insoluble substances are separated and the mother liquor consists of nickel-ammonium sulphate in solution with ammonium sulphate. The solution is evaporated to deposit nickel-ammonium sulphate, and a further amount is obtained from the separated solution.

H. G. POOLE, S. F. RAVITZ and K. C. DEAN, assignors to UNITED STATES OF AMERICA. *U.S. Pat.* 2,520,958.

Production of Nickel Carbonyl

A nickel compound or mixture of compounds produced by the action of an alkaline reacting substance upon an aqueous solution of a nickel salt is treated in aqueous solution or suspension with carbon monoxide under superatmospheric pressure, in the

presence of a small amount of nickel sulphide or cyanide, and a substance of alkaline reaction. A typical example of procedure is described.
CIBA, LTD. *Brit. Pat.* 649,988.

Sintered-Nickel Accumulator Plates

Porous metal plates suitable for alkaline accumulators are made by sintering metal powder between two formers having rough or corrugated surfaces, the depth of the corrugations or surface roughenings being very small, but serving to prevent contraction parallel to the main surfaces of the plate. The formers may be made from unglazed ceramic material and the powder is preferably nickel powder in the form of interlocked aggregates having a bulk density between 0·3 and 1·2 grams per cc.
MOND NICKEL CO., LTD., and M. A. COMLEY.
Brit. Pat. 648,415.

A related patent describes plates built up by successively sintering a number of layers of powder without subjecting them to pressure, each layer being united to the previous one by the sintering, and being so thin that it undergoes substantially no contraction parallel to the surface of the plate during sintering. Apparatus for carrying out the process is described. The preferred powder is the same as that described in 648,415.
MOND NICKEL CO., LTD. and H. W. G. HIGNETT.
Brit. Pat. 648,929.

Nickel Oxide in Alkaline Dry Cells

An alkaline primary dry cell has an anode or anodes of amalgamated zinc, and a cathode or cathodes of depolarizer material comprising nickel, iron, cobalt, or manganese oxide produced by electrolytically converting a hydroxide of the metal to oxide. The electrodes are in contact with an immobilized electrolyte comprising an alkali metal hydroxide and a substantial quantity of alkali metal zincate. The depolarizer material may consist of a compacted mixture of nickel-oxide powder and a small quantity of finely divided material inert to the electrolyte and of higher electrical conductivity than nickel oxide, e.g., micronized graphite.
MALLORY BATTERIES, LTD. *Brit. Pat.* 647,362.

Preparation of Basis Materials for Nickel Plating

Surfaces composed partly of solder and partly of steel or nickel are prepared for plating by making them the anode in a concentrated aqueous solution of sulphuric acid and orthophosphoric acid, so that an electrically-conducting film is formed which is resistant to penetration or removal by the plating solution.
W. B. STODDARD, assignor to CHAMPION PAPER AND FIBRE CO. *U.S. Pat.* 2,533,533.

Deposition of Nickel by Chemical Reduction

By means of an autocatalytic chemical reduction process nickel is continuously deposited on objects of iron, platinum, silver, nickel, gold, cobalt, palladium, aluminium and copper. The object to be plated is immersed in an aqueous solution of a nickel salt and an alkaline hypophosphite, and is plated by autocatalytic reaction of the salt and hypophosphite. During the immersion the solution is kept at a temperature of 90°-100°C. and a pH of 3-9 is maintained by the presence of a sodium salt of a carboxylic acid or an ammonium salt. At regular intervals throughout the immersion period additional hypophosphite is introduced.
A. BRENNER and G. E. RIDDELL. *U.S. Pat.* 2,532,283.

Arc-Welding Nickel-Iron Electrode

An arc-welding electrode consists of a core of nickel-iron alloy (40-75 per cent. nickel). The flux coating is of the type described in Brit. Pat. 621,936.
MOND NICKEL CO., LTD.
Brit. Pat. 645,958 (addition to 621,936).

Nickel-Alloy Cast Irons for Automotive Components

Cylinder liners, piston rings, valve-seat inserts, valve guides, etc., are made from irons of compositions chosen to give an austenitic structure, and the composition/cooling rate relations are so controlled that the castings possess initially an excess proportion of carbides, and are subsequently heat-treated to reduce the carbides to the desired amount and particle size. Typical irons covered contain (*a*) carbon 2·5-3·5, silicon 1·0-3·0, phosphorus 0·2-1·0, nickel 12-16, copper 5-8, chromium 2-5, molybdenum up to 4·0, vanadium up to 1·0, per cent., and (*b*) carbon 2·5-3·2, silicon 1·5-3·0, phosphorus 0·2-1·0, manganese 3·5-6·0, nickel 10·0-15·0, chromium 1·5-4·0, molybdenum up to 4·0, vanadium up to 1·0, per cent.
BRITISH PISTON RING CO., LTD., and T. R. TWIGGER.
Brit. Pat. 647,629.

Precipitation-Hardening Nickel-Chromium-Cobalt Steels for High-Temperature Service

An austenitic steel having good hot-working properties, resistance to creep, and good life and strength at high temperatures contains carbon 0·03-0·20, chromium 12-22, nickel 10-22, cobalt 5-20, manganese up to 2·0, molybdenum 2-4, copper 2-4, titanium 0·15-0·75, and/or niobium 0·2-1·1, per cent., remainder iron. The steel is solution-heated at 2050°-2250°F. (1120°-1230°C.), quenched, and re-heated at 1200°-1500°F. (650°-815°C.).
W. C. CLARKE, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,536,033.

In a closely related patent the composition limits are given as chromium 12-22, nickel 5-10, cobalt 4-40, manganese up to 2·0, molybdenum 1-4, copper 2-4, carbon 0·01-0·35, titanium 0·15-0·75, niobium 0·20-1·10, per cent., remainder iron. Heat-treatment is as in 2,536,033.
W. C. CLARKE, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,536,034.

Cast Heat-Resisting Alloy for Gas-Turbine Components

A cast alloy claimed to be particularly suitable for gas-turbine blading is characterized by a titanium content of 3-10 per cent. and a high nitrogen content.

Limits of composition are given as carbon 0·01-0·5, chromium 15-25, nickel 10-30, titanium 3-10, cobalt 5-20, nitrogen 0·05-0·5, per cent. Tungsten, molybdenum and vanadium may be present in amounts from 1 to 15 per cent. Heat-treatment comprises heating at 2192°-2372°F. (1193°-1298°C.) for one hour. An example cites a cast alloy containing carbon 0·35, nitrogen 0·2, chromium 21, nickel 25, cobalt 10, titanium 5, molybdenum 6, per cent., for which creep values are given.

STE. ANON. ETABLISSEMENTS JACOB HOLTZER. *Brit. Pat.* 648,422.

Heat-Resisting Steels for I.C.E. Valves and Gas-Turbine Blading

Steels which are resistant to high temperature and to temperature variation, and are corrosion-resistant, contain carbon about 1·0, chromium 12-26, nickel 3-20, from 1·2-6·0 per cent. in total of molybdenum, tungsten and niobium, remainder iron. The steels may also contain up to 2·5 per cent. each of manganese and silicon, up to 0·25 per cent. nitrogen and up to 20 per cent. cobalt. They are suitable for valves of internal-combustion engines, and for gas-turbine blading.

G. MOHLING and T. Y. WILSON, assignors to ALLEGHENY LUDLUM STEEL CORPN. *U.S. Pat.* 2,537,477.

Heat- and Corrosion-Resisting Valve Alloys

The main feature of the invention is the production, without heat-treatment, of a corrosion- and heat-resisting ferrous alloy. Composition limits: carbon 0·3-0·7, manganese 0·5-2·5, silicon 0·5-1·5, chromium 20-25, nickel 20-25, molybdenum 2·0-4·0, copper 5·0-6·5, aluminium 0·5-1·5, niobium 0·5-1·0, per cent., and up to 0·03 per cent. each of sulphur and phosphorus. Such alloys are claimed to be suitable for use in valves and other parts operating under corrosive conditions at high temperatures, e.g., in oil refineries. The patent includes a detailed discussion of the specific function of each of the constituent elements.

V. T. MALCOLM, assignor to CHAPMAN VALVE MANUFACTURING CO. *U.S. Pat.* 2,523,838.

Heat-Resisting Steels for Gas-Turbine Components and Valves

Austenitic heat-resisting steels contain carbon 0·08-1·0, silicon 0·1-2·0, manganese 0·1-5·0, nickel 5-30, chromium 21-5, tungsten and/or molybdenum 1·5-15, niobium (with or without tantalum) 0·25-15, cobalt 3-30, nitrogen up to 0·3, copper up to 6·0, iron not less than 33, per cent. Nickel+chromium is at least 24 per cent., and the niobium is at least 0·05 per cent. when tantalum is present. Vanadium may replace part of the niobium, or niobium+tantalum, the content of niobium or niobium+tantalum not falling below 1·0 per cent. when vanadium is present. A preferred composition is given as carbon 0·4, manganese 0·8, silicon 1·0, nickel 13, chromium 13, cobalt 10, tungsten 2·5, molybdenum 2·0, niobium and/or tantalum 3·0, nitrogen 0·04, iron 54·26, per cent.

WILLIAM JESSOP AND SONS, LTD., D. A. OLIVER and G. T. HARRIS. *Brit. Pat.* 647,701.

Precipitation-Hardening Complex Nickel-Chromium Steel for High-Temperature Service

A forgeable and machinable age-hardenable austenitic steel contains carbon 0·4-0·8, nickel 13·5-16, manganese 3·5-10·0, chromium 10-15, silicon 0·2-2·5, aluminium 2·5-4·0, nitrogen up to 0·3, per cent., and up to 5·0 per cent. total of other elements which do not impair the age-hardening properties of the steel. The required properties are produced by solution treatment at 2300°F. (1260°C.), followed by ageing at 1300°F. (705°C.). Hardness of Rockwell C 35 is so produced.

P. PAYSON, assignor to CRUCIBLE STEEL CO. OF AMERICA. *U.S. Pat.* 2,523,917.

Nickel-base Hard-Surfacing Alloy

An alloy suitable for hard-facing purposes and for welding rods contains silicon 5-18, cobalt 5-30, copper 10-30, chromium up to 15·0, iron up to 15·0, per cent., remainder nickel (between 35·0 and 65·0 per cent.). Chromium+iron does not exceed 20·0 and nickel+iron is not more than 65 per cent.

W. A. WISSLER, assignor to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,521,273.

Decorative Corrosion-Resisting Steel

A stainless steel from which ornamental articles having a silver-white appearance can be made by cold working and polishing contains nickel 18, chromium 8, copper 1, per cent.

J. M. DEFRANOUX, assignor to STE. D'ELECTROCHIMIE, D'ELECTRO-METALLURGIE ET DES ACIERIES ELECTRIQUES D'UGINE. *U.S. Pat.* 2,523,000.

Nickel-Chromium-Aluminium Electrical Resistance Alloys

The alloys claimed contain chromium 10-30, aluminium 2-4, per cent., balance nickel. After annealing at 1700°-2000°F. (926°-1093°C.) and subsequently heating for 1-5 hours at 900°-1100°F. (482°-593°C.) a temperature coefficient of resistance below 0·00008 is obtained.

J. M. LOHR, assignor to DRIVER-HARRIS CO. *U.S. Pat.* 2,533,735.

According to a related patent the alloys also contain 0·3-6·0 per cent. manganese.

J. M. LOHR, assignor to DRIVER-HARRIS CO. *U.S. Pat.* 2,533,736.

NOTE.—The subject matter of both patents is covered by Brit. Pat. 621,343.

Nickel-containing Watch-Spring Alloys

Articles having high elastic properties e.g., watch springs, are made from alloys containing cobalt 20-50, chromium 15-30, nickel 5-31, iron 0-18, per cent. (iron +nickel being not less than 20 per cent. and the iron being preferably less than the nickel), manganese 0-3, carbon 0-0·3, beryllium 0·01-0·09, per cent. A blank of the alloy is quench-annealed from 2000°-2200°F. (1093°-1204°C.), cold-worked until the increased hardness makes further cold-working impracticable, and aged at 500°-1000°F. (260°-538°C.)

until the yield strength exceeds 220,000 p.s.i. (98·2 tons per sq. in.).

ELGIN NATIONAL WATCH CO., assignee of O. E. HARDER and D. A. ROBERTS.

Brit. Pat. 647,760. *Brit. Pat.* 647,819.

In a related patent the composition is modified as follows:—cobalt 20-50, chromium 15-30, molybdenum 1-10·0 per cent. (molybdenum+chromium 20-37 per cent.), nickel 15-50, iron 0-15, manganese 0-5, per cent. (iron+nickel+manganese being 20-50 per cent. and the nickel being greater than the iron), carbon 0·05-0·3, beryllium 0- less than 0·01, per cent. The quench-annealing temperature is 1800°-2300°F. (980°-1260°C.) and ageing is effected by heating at 500°-1200°F. (260°-648°C.). The yield strength in this case is at least 250,000 p.s.i. (111·6 tons per sq. in.).

ELGIN NATIONAL WATCH CO., assignee of O. E. HARDER and D. A. ROBERTS. *Brit. Pat.* 647,783.

Titanium-Stabilized Nickel-Chromium-Steel Welds

In arc-welding high-chromium and austenitic nickel-chromium steels, quantities of titanium sufficient to ensure stabilization are introduced into the welds by using a ferrous alloy core coated with a flux containing 10-40 per cent. by weight of a powdered single alloy consisting of titanium 9-15 per cent., one or more of the metals, lithium, potassium, strontium, cerium, calcium, sodium, magnesium, aluminium and beryllium, 64-20 per cent., balance (if any) being iron. The single alloy may contain varying amounts of chromium, nickel, silicon, manganese and copper. A weld deposit claimed contains chromium 16-21, nickel 7-12, manganese 0·3-3·0, silicon 0·03-3·0, copper 0·3-3·0, carbon 0·01-0·2, per cent. at least 4½ times as much titanium as carbon, balance iron.

F. B. DEHN, commn. from TITANIUM ALLOY MANUFACTURING CO. *Brit. Pat.* 646,777.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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